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An Analysis of Price and Supply Relationships In the U.S. Brussels Sprouts Industry

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FOREWORD

This study is one of a series that has dealt with the competitive position of the western fruit and vegetable industry, with particular emphasis on vegetables utilized for freezing. It differs from the previous studies in its econometric orientation and its focus on the total economic structure of the commodity sector, rather than the frozen component alone. The model developed simulates the dynamic processes of production and price adjustment within the Brussels sprouts industry. With the aid of a computer, it is used to inquire conditionally into the potential future impacts of changes in demand, product competition, technology, and market policies. Similar studies are in progress for other vegetables, including asparagus, broccoli, cauliflower, green lima beans, spinach, and snap beans.

This study is part of the work carried on by the California Agricultural Experiment Station under Western Regional Marketing Research Project WM-47 in cooperation with the experiment stations of Oregon, Washington, Idaho, and Hawaii and with the Economic Research Service, U.S. Department of Agriculture. A part of the financial support for the present study was provided by the California Brussels sprouts industry through the Brussels Sprouts Marketing Program.

We gratefully acknowledge the assistance of Walter J. Englund, California Department of Agriculture, Bureau of Marketing, and the cooperation of the several processing firms that made available the data required for the analysis of sprout size relationships. Names of the latter are omitted to avoid possible disclosure of operations. We are especially indebted to our colleagues Gordon A. King and Samuel H. Logan for most helpful reviews of an initial draft of the report.

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AN ANALYSIS OF PRICE AND SUPPLY RELATIONSHIPS
IN THE U.S. BRUSSELS SPROUTS INDUSTRY

by

Ben C. French* and Masao Matsumoto**

INTRODUCTION

In 1957, after appropriate hearings and favorable vote of growers, the California Director of Agriculture issued an order establishing a Marketing Program for California Brussels Sprouts for Freezing. This action followed several years of declining prices and was taken to provide a legal mechanism whereby quantities of Brussels sprouts utilized for freezing (about 70 percent of total production) might be controlled and a price level more favorable to growers reestablished. Subsequent amendments have provided for regulation of grades and sizes of sprouts frozen, as well as total quantity.

Committees or boards charged with administering such marketing programs need to have at their disposal both economic data and knowledge of relationships among the important economic variables affecting the commodity. As a minor product in the total agricultural economy, Brussels sprouts have received relatively limited attention from data collection agencies and economic analysts. Consequently, members of the Brussels sprouts industry have had to make production and marketing decisions on the basis of rather incomplete knowledge of important aspects of their economic environment and the probable short- and long-run consequences of their decisions.

The purpose of this study is to develop economic information which may aid the thinking of leaders in the Brussels sprouts marketing program

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and also be of value to individual firms, growers, and public agencies concerned with the industry. The specific objectives are: (1) to develop a quantitative description of the economic environment and behavior of the system within which Brussels sprouts are produced and marketed; (2) to explore relationships among the economic variables involved in this system; and (3) from the above, to formulate models which simulate, by computer, the functioning of the Brussels sprouts economy and the possible consequences of alternative policies or changes in the economic environment.

The material that follows is presented in five major sections. The first describes some of the important characteristics of the commodity and the industry. The second section describes the economic structure of the Brussels sprouts economy in terms of the apparent relationships among price and supply variables at different times and levels within the system. The next section develops quantitative measurements of the major types of economic relationships involved. Section four combines materials of the previous sections to formulate a model of industry development over time, including both regional and fresh and frozen commodity components. The model is then used to explore some possible effects of alternative market control policies and other changes in the environment. The last section investigates some economic aspects of controlling or changing the distribution of individual sprout sizes.

COMMODITY AND INDUSTRY CHARACTERISTICS

Production of Brussels Sprouts

Brussels sprouts, a member of the cabbage family, grow best in climates that provide cool weather during the maturation period. Soils need to be well drained, fertile, and free of salt and alkali. The coastal district of California from Half Moon Bay to Castroville ideally provides these conditions and historically has been the leading producing region in the United States.[1/] New York ranks a distant second. Small quantities

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1/ For detail on California acreage by county, see Appendix Table A-1.

also have been produced in other states in the East, Southwest, and the Pacific Northwest.

The Brussels sprouts industry is small by comparison with the production of many other agricultural commodities. In 1964 there were 63 producers in California with an average of 85 acres per grower (see Table 1). The gross farm value of California's production (in 1964) was approximately $7,300,000, or about $1,377 per acre. It is clearly an intensively farmed commodity. The 1964 farm value of total United States production for fresh and frozen markets was about $7,900,000. More recent values have been about the same or slightly higher.

The freezer component of the industry involves about nine California firms plus perhaps three or four in other regions. Based on price and production data shown in the appendix tables, we estimate the California value in recent years at roughly $11,000,000 and the United States value at about $12,800,000, f.o.b. freezer plant. Value added by U.S. freezers--f.o.b value less cost of raw product--has been in the neighborhood of $7,000,000.

Changes in total production, acreage, and yield since 1949 are shown in Figure 1.[1/] California acreage fluctuated--in fact, appeared to cycle--around a fairly constant average level during the period from 1949 to 1958. Following the establishment of the Marketing Program for Brussels Sprouts for Freezing, acreage changes have been much smoother, with a gradual upward trend. Yields, which moved generally upward until 1960, have since stabilized or even declined. The latter may be due to adjustments in varieties and harvest methods. California production also fluctuated widely prior to 1958, but with an upward trend due primarily to the increases in yield. Since then production has leveled off and been more stable.

Production and acreage in New York remained small and mostly stable over most of the period since 1949, but with some increase since 1961. The changes illustrated in Figure 1 do not include unreported production in minor states. Production from these areas is included in the utilization data presented next.

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1/ See Appendix Table A-2 for data and sources.

TABLE 1

Changes in the Number of California Farms
Reporting Brussels Sprouts Production
and Average Acreage per Farm,
1940-1964

Year	Number of farms	Acres	Average acres per farm
1940	133	3,082	23
1950	130	3,966	31
1954	84	4,645	55
1959	79	5,312	67
1964	63	5,344	85

Source: *Census of Agriculture*, USDC, Bureau of the Census, Washington, D.C.

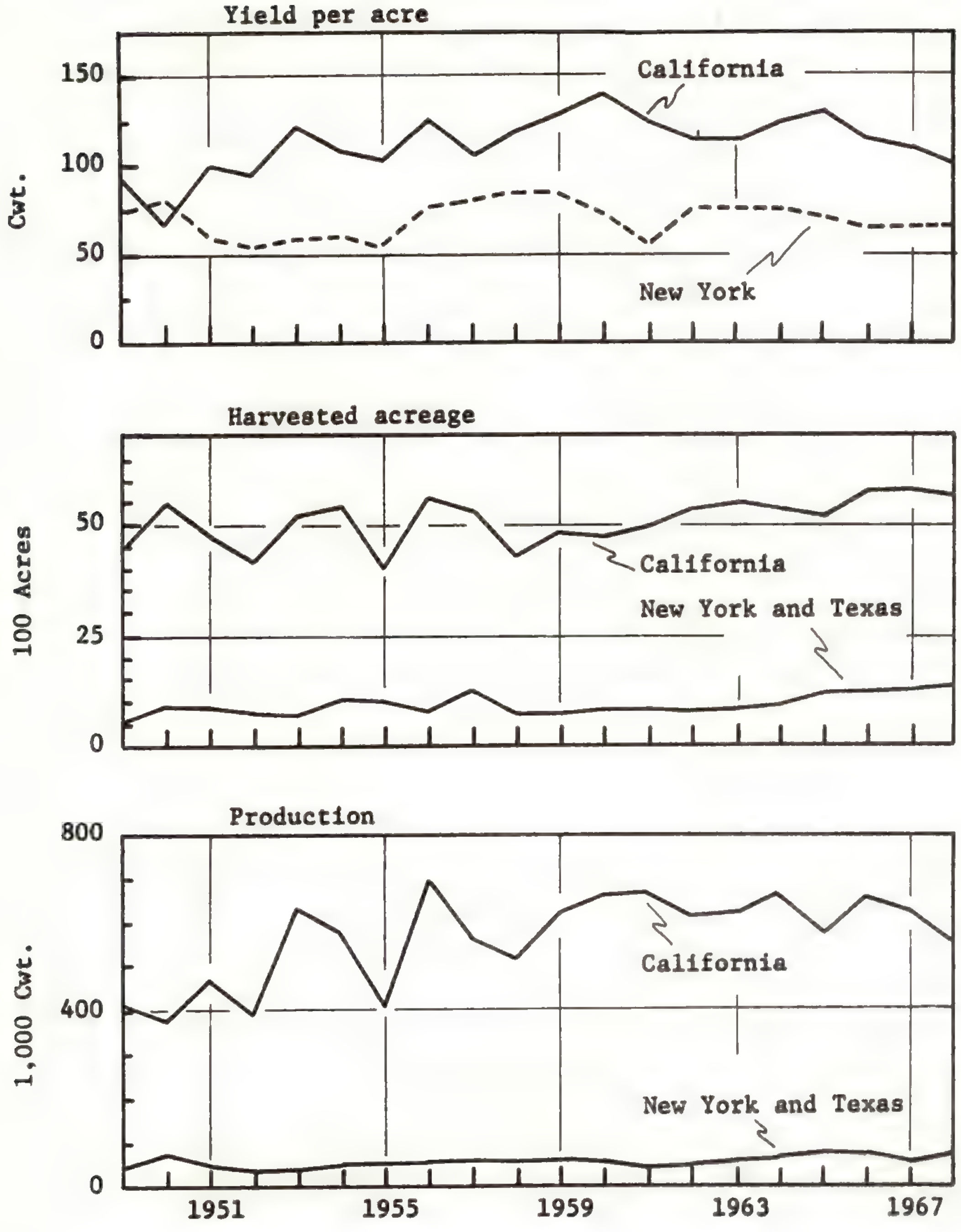

FIGURE 1

Production, Acreage, and Yields of Brussels Sprouts
by Region, 1949-1968

Utilization of Brussels Sprouts

Figure 2 shows how the total production of Brussels sprouts has been allocated between fresh market and processing uses.[1/] Two things seem especially worthy of comment. The first is the rapid increase in California quantities utilized for freezing, while average fresh quantities remained about level, then declined slightly in recent years. The second thing is the accelerated rate of increase of frozen production in other regions beginning in the 1960's. We shall have more to say about this in later sections.

Figures 3 and 4 express the information in Figure 2 in relative terms.[2/] Figure 3 shows how the percent of Brussels sprouts production utilized for freezing has changed in California and the rest of the United States. Whereas the California allocation has been somewhat constant, the proportion of production that is frozen in other regions has increased dramatically in recent years. Even if we allow for some error in our crude estimates of total fresh production, the magnitude of change seems clearly indicative of significant shifts in utilization of sprouts produced outside California.

Figure 4 shows how California's share of U.S. fresh and frozen production has been changing. With the shift toward freezing in other regions, California has taken over an increasing share of the fresh market and a decreasing share of the frozen production.

Changes in total United States pack of frozen Brussels sprouts and the allocation among major container sizes are illustrated in Figure 5. The retail size class includes all containers weighing one pound or less and institutional sizes includes all containers larger than one pound, regardless of their ultimate sales destination. The percentage of

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1/ Data on quantities utilized fresh are not published. The values in Figure 2 were obtained by applying a conversion factor to frozen pack to obtain raw product weight and subtracting this from total production to obtain estimates of fresh market quantities. See Appendix Table A-3 for details.

2/ See Appendix Table A-4 for data.

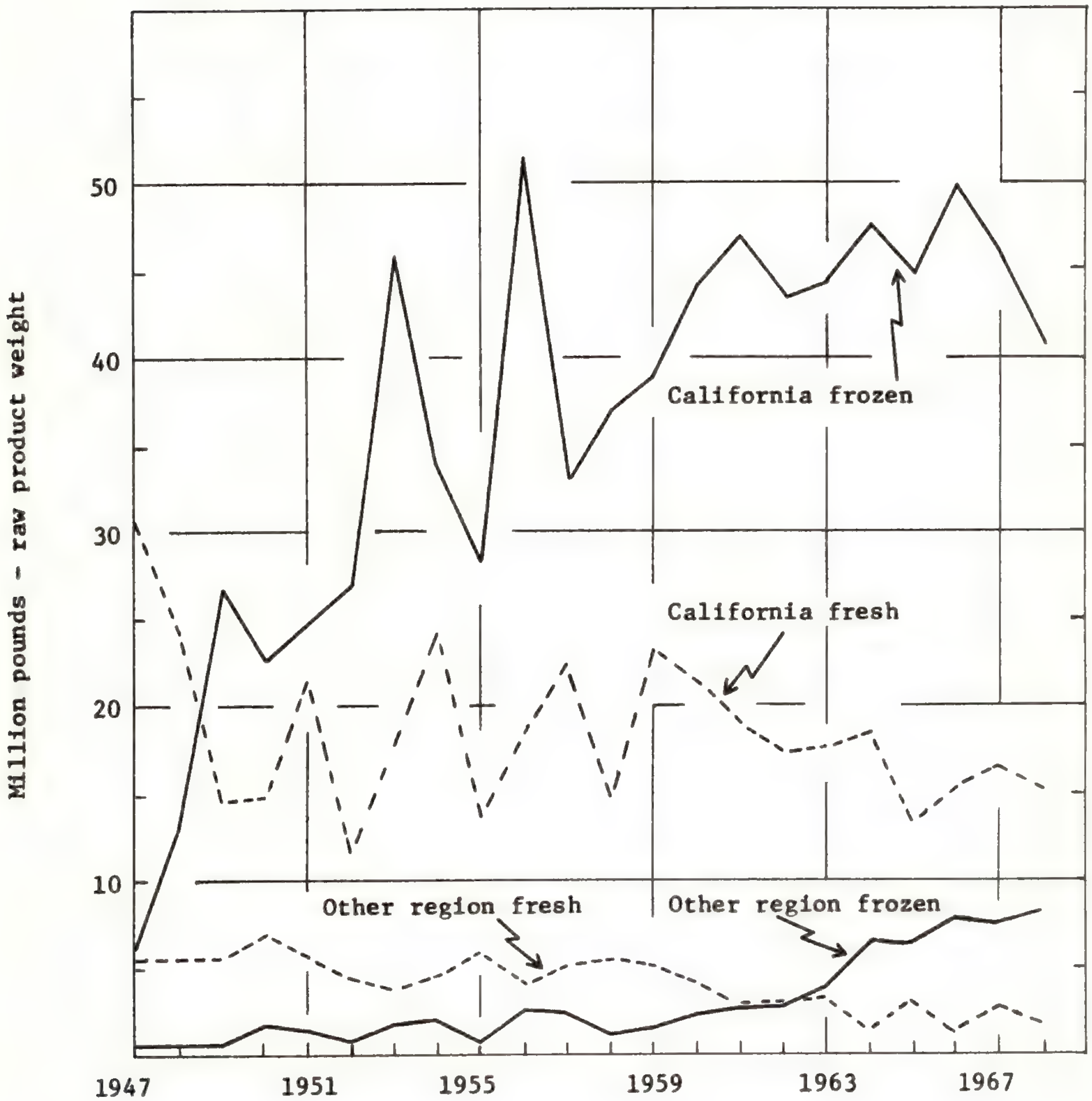

FIGURE 2

Utilization of United States Brussels Sprouts Production, by Region, Crop Years 1947-1968

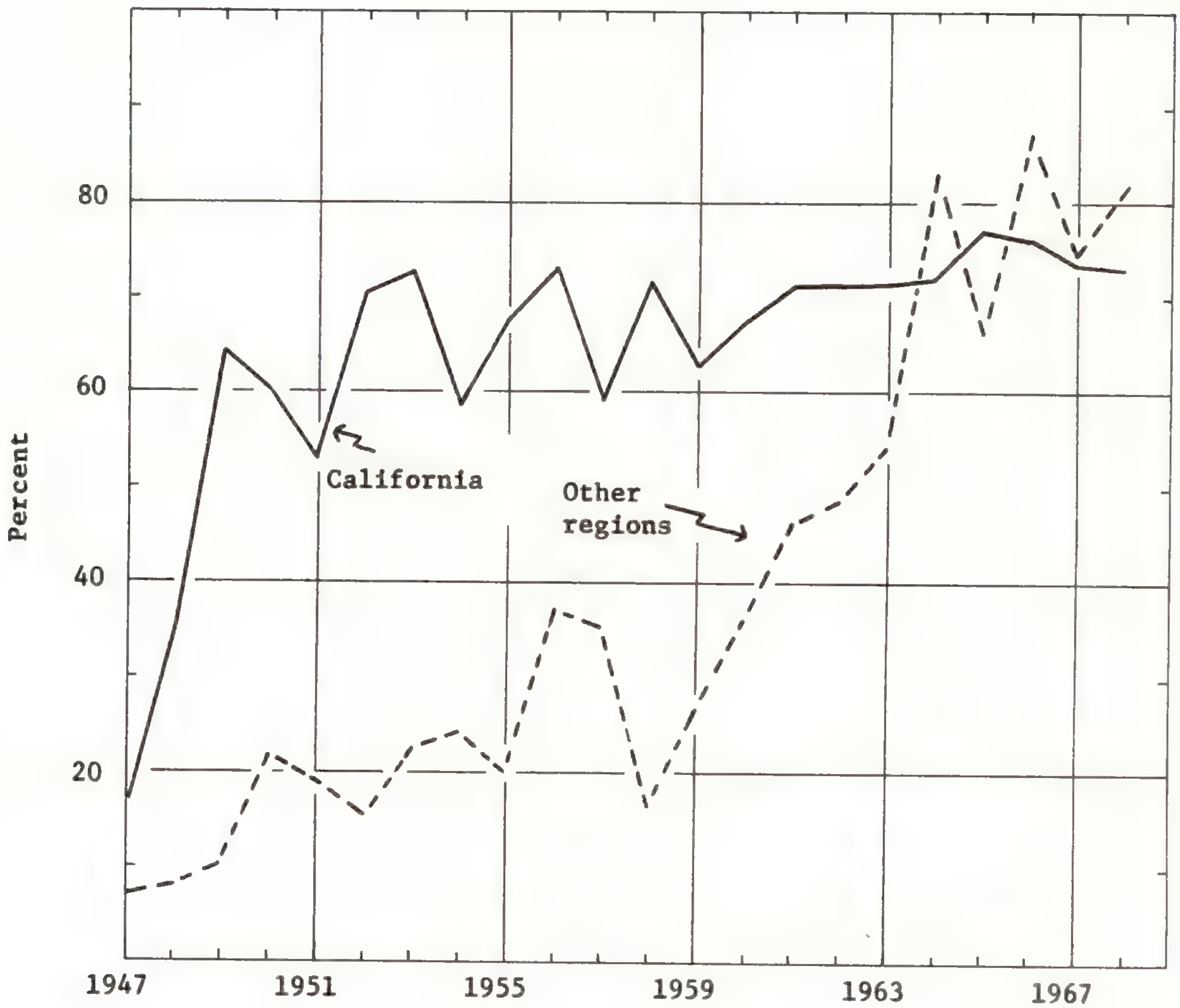

FIGURE 3

Regional Changes in Shares of Brussels Sprouts Utilized for Freezing, Crop Years 1947-1968

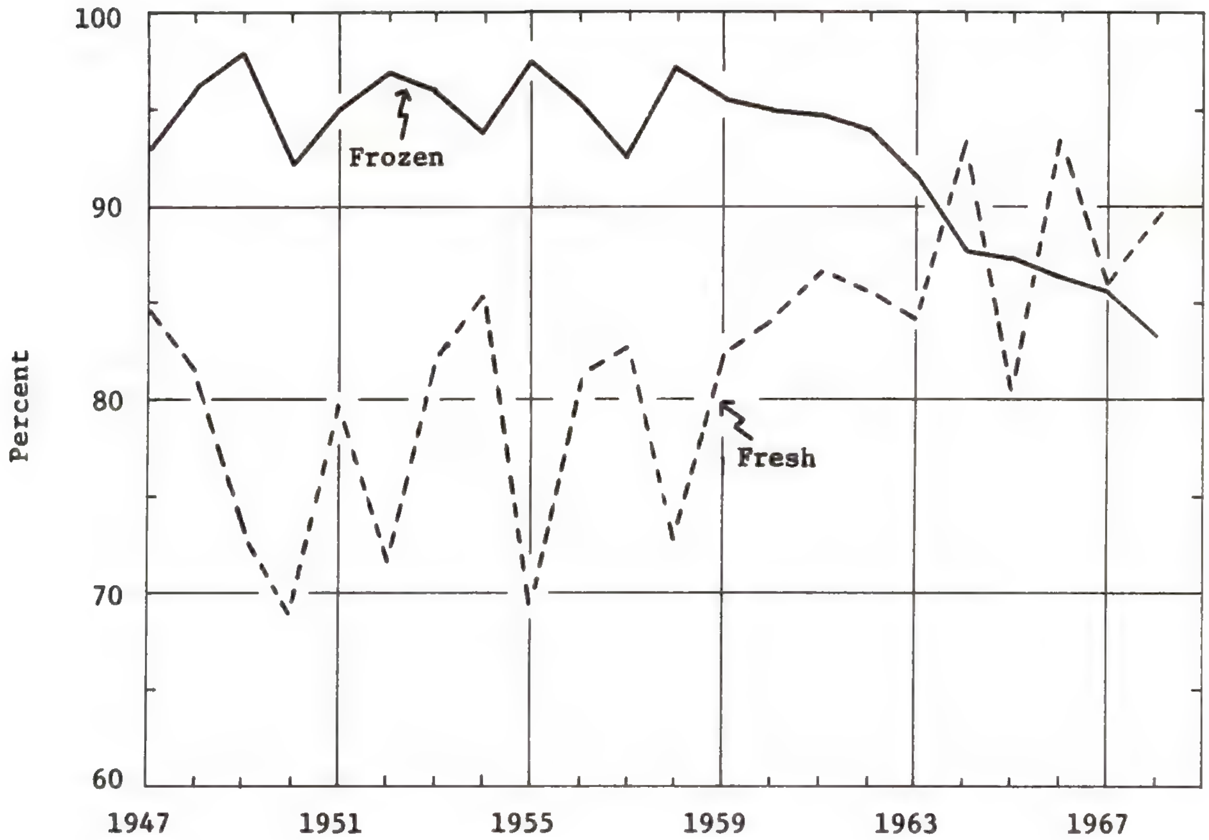

FIGURE 4

California's Share of United States Brussels Sprouts
Production, Crop Years 1947-1968

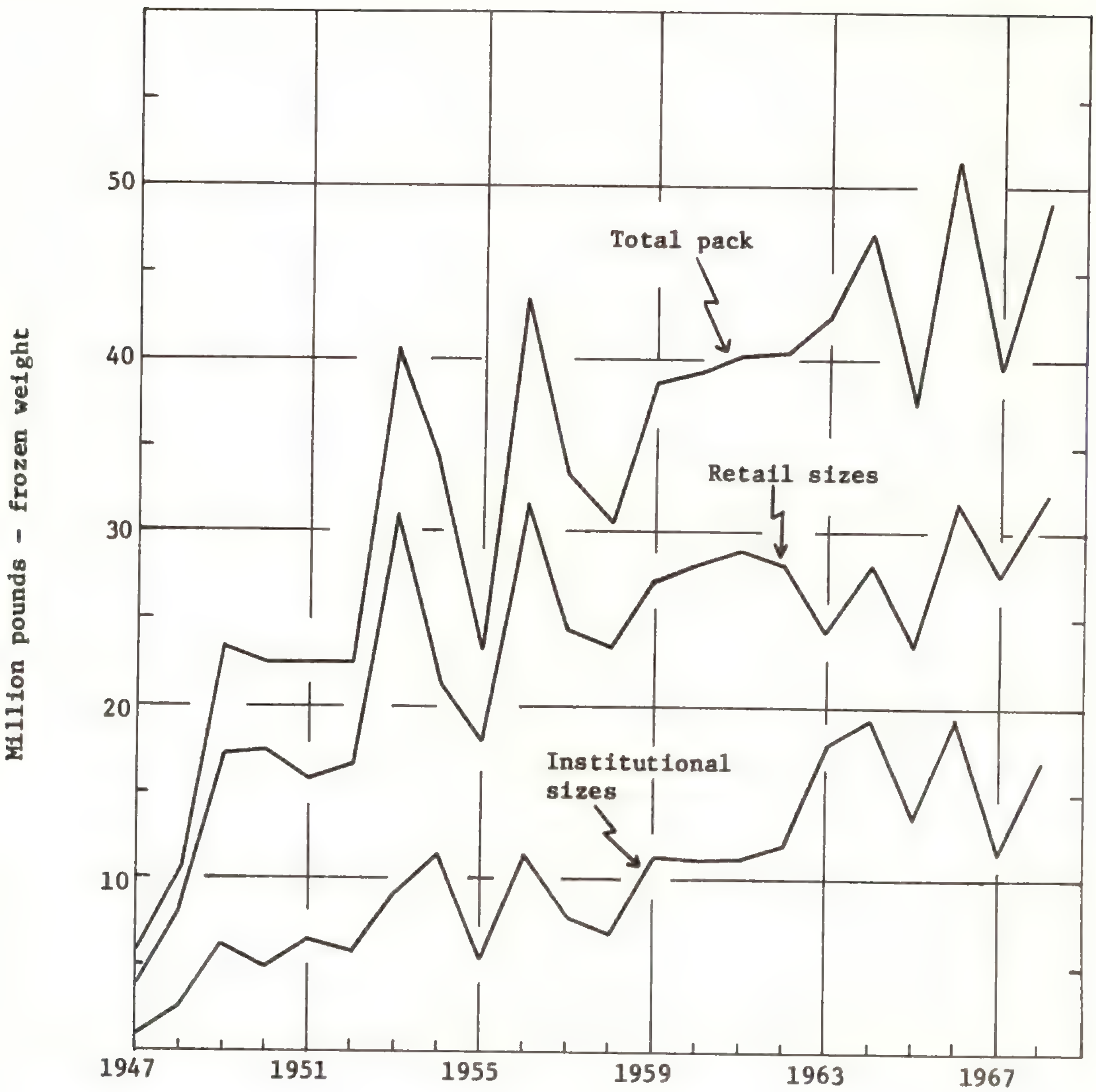

FIGURE 5

United States Frozen Brussels Sprouts Pack by Major Container Size Groups, Calendar Years 1947-1968

production in the smaller container sizes has declined from an earlier high of 77 percent to well under 70 percent in most recent years (see Appendix Table A-6).

The size of individual Brussels sprouts also varies somewhat, with smaller sizes typically commanding a price premium. Published pack statistics do not reveal the proportions of production falling in different size classes. An indication of the nature of this distribution is available for two periods from special surveys of freezers by the authors. The results are summarized in Table 2. The upper part of the table shows the relative importance of pack by three size groupings for packers accounting for about 65 percent of the frozen pack during 1961 and 1962. Figures in the bottom part were computed from the 1964-1968 records of a major freezer. Since the "large" category includes some B grades or otherwise unclassified sprouts, the figures may slightly overstate the proportions falling in this class. It is clear, however, that medium sizes account for the majority of the pack, with small sizes a relatively small fraction. In later sections we shall explore the relation of size to price and investigate the potential effects of changes in distribution on industry net revenue.

Temporal Distribution of Production and Sales

The production season for California Brussels sprouts starts toward the end of August or early September and normally ends in February or the first part of March. This terminates the fresh market operation except for imports, mostly from Mexico, and minor quantities from scattered locations. The market flow of the frozen product continues from storage holdings throughout the year.

Figure 6 shows shipments of fresh Brussels sprouts originating in the United States for two recent years, illustrating both early and late seasons.[1/] Comparable data for earlier years are not available. Actual consumption or unloads may differ from shipments because of quantities exported to Canada and imported from Mexico. Figure 7 shows the distribution of United States

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1/ See Appendix Table A-7 for data, including the intervening years.

TABLE 2

Size Distribution of Brussels Sprouts, 1961-1962 Survey and 1964-1968 Single Packer Sample

	1961-1962 Survey[a]		
	Large[b]	Medium	Small
	percent of total		
Retail sizes	13.5	68.8	17.7
Institutional sizes	39.3	53.2	7.5
TOTAL	21.0	64.2	14.8
	1964-1968 Sample		
	Large and unclassified	Medium	Small
TOTAL	28.6	60.7	10.7

a/ Size classes were established as follows: Large--less than 25 per pound and including B grade, Medium--25 to 40 per pound, Small--over 40 per pound, trimmed basis.

b/ Includes B grade.

Source: Calculated from survey records.

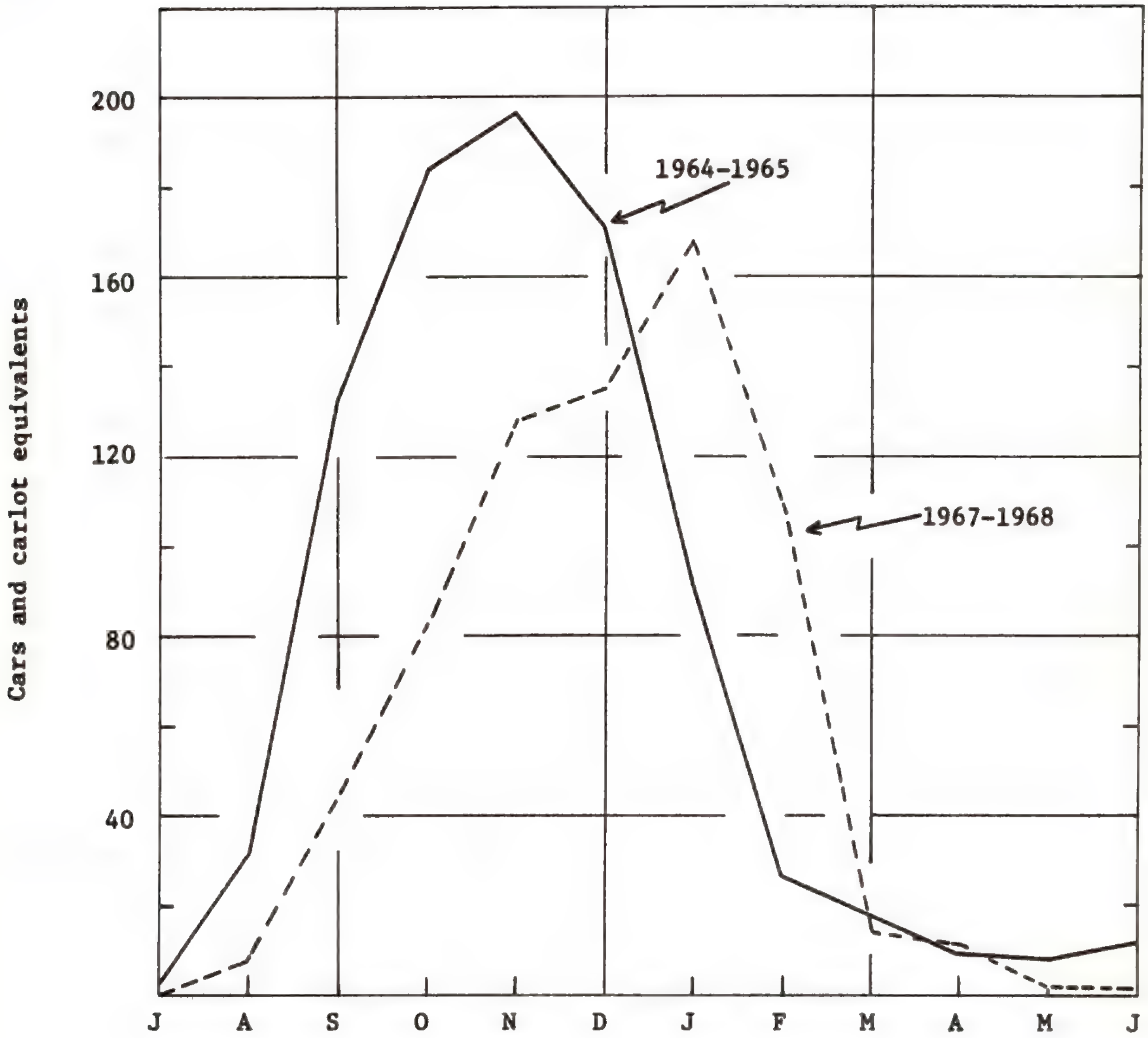

FIGURE 6

United States Shipments of Fresh Brussels Sprouts, 1964-1965 and 1967-1968

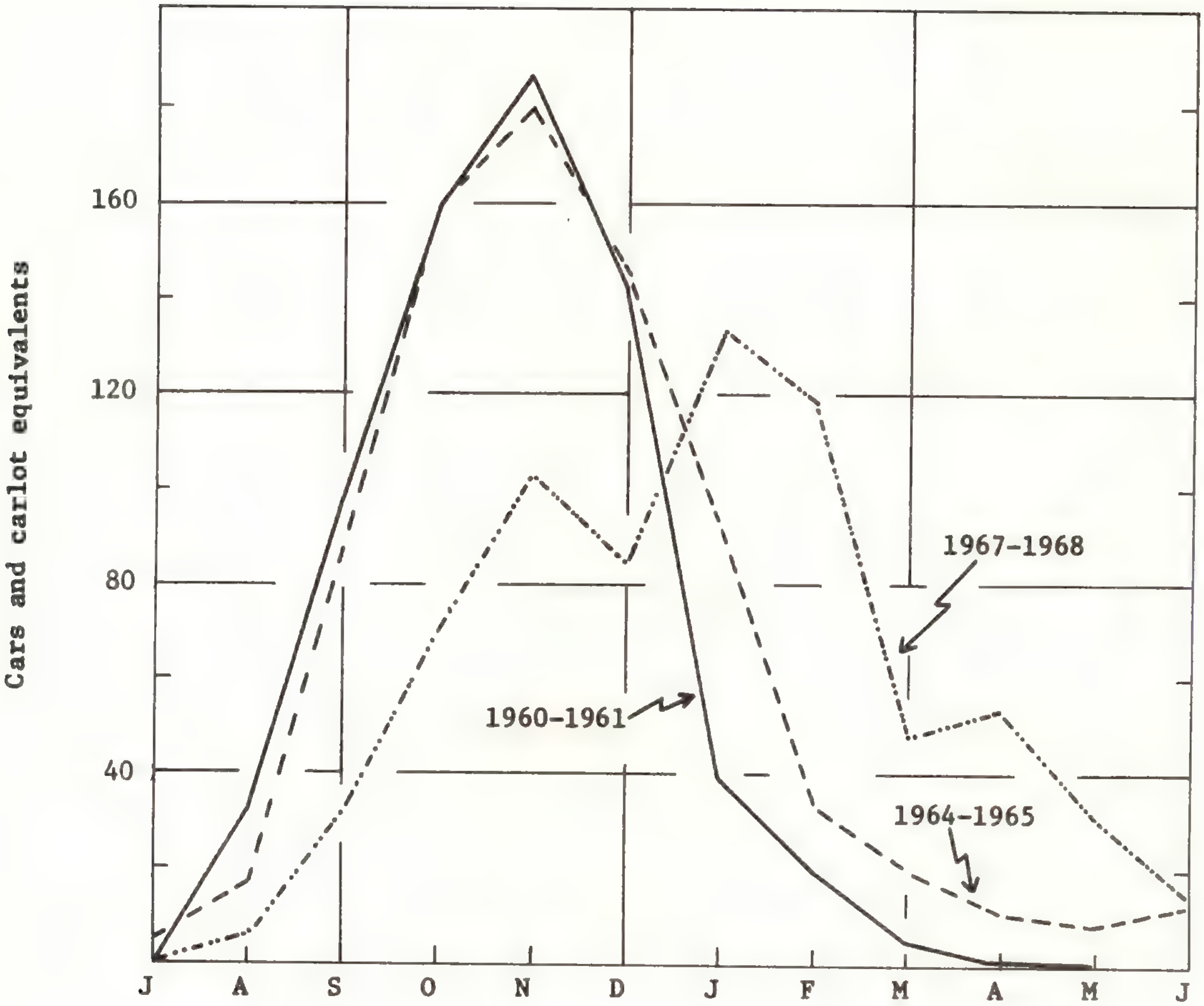

FIGURE 7

Carlot Unloads of Fresh Brussels Sprouts in 41 United States Cities, 1960-1961, 1964-1965, and 1967-1968

carlot unloads which may correlate closely with consumption, for three selected years.[1/] Note that unloads exceed U.S. shipments during the spring months, especially in 1967-1968, reflecting the increased imports from Mexico.

The time distribution pattern for California's frozen pack is shown in Table 3. In most years more than 90 percent of the pack is frozen by January 1, with October the month of heaviest production.

Table 4 shows the relative movement out of the hands of freezers by quarters. The September-November quarter is usually the period of heaviest sales, followed closely by December-February. Summer sales are lowest. Since there may be some lag in movement out of storage and through the marketing system, the pattern of actual consumption may be shifted somewhat more toward spring than indicated in Table 4. The table also shows how storage stocks build up and are reduced throughout the year. In most years, stocks at the end of the crop year are between 20 and 30 percent of crop year movement.

Imports and Exports

As indicated in the previous discussion, significant quantities of fresh Brussels sprouts have been imported from Mexico and other quantities exported to Canada. Small quantities of frozen Brussels sprouts also are imported, primarily from Belgium and the Netherlands. Presumably, some frozen quantities are exported, at least to Canada, but identifiable records of such movements are not maintained.

Appendix Table A-12 summarizes the available import and export data for the period beginning in 1963 to date. Reliable data pertaining to quantities of fresh imports apparently are not available on a consistent basis prior to 1963 and even the recent figures involve some uncertainty as to their interpretation (see Table A-12 footnotes). More years of data are available on frozen foreign imports and the data may be slightly more meaningful. However, frozen imports have never been more than about 3 percent of total domestic production and seldom as much as 2 percent.

1/ See Appendix Table A-8 for data, including the intervening years.

TABLE 3

Percent of Annual California Frozen Brussels Sprouts Production Packed by Months, 1959-1968

Year	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
1959-1960		30.1	39.4	14.5	16.0		
1960-1961		25.6	38.1	21.5	12.6	2.2	
1961-1962		31.7	27.3	17.2	16.7	7.0	0.1
1962-1963		27.3	34.2	17.8	13.0	7.7	
1963-1964		17.3	29.3	34.0	13.1	6.3	
1964-1965	7.0	35.9	36.9	16.2	4.0		
1965-1966		12.9	38.9	21.1	13.2	10.5	3.4
1966-1967	7.8	22.7	26.0	20.5	19.6	3.4	
1967-1968		20.3	19.9	19.8	20.1	16.4	3.5
AVERAGE	1.6	24.9	32.2	20.3	14.3	5.9	0.8

Source: Computed from Appendix Table A-9.

TABLE 4

Quarterly Movement and End of Quarter Storage Holdings of California Frozen Brussels Sprouts as Percent of Crop Year Movement

Year	Movement				End of period storage holdings			
	Sept.-Nov.	Dec.-Feb.	Mar.-May	June-Aug.	Sept.-Nov.	Dec.-Feb.	Mar.-May	June-Aug.
	percent of crop year movement							
1959-1960	28.0	35.4	22.4	14.2	74.1	53.8	31.4	17.2
1960-1961	38.5	18.4	32.6	10.5	74.4	72.5	39.9	29.4
1961-1962	32.4	29.2	22.8	15.6	70.4	65.5	42.7	27.1
1962-1963	32.0	31.0	22.5	14.5	71.3	60.1	37.7	23.2
1963-1964	30.7	27.4	21.1	20.8	67.5	58.5	37.4	23.6
1964-1965	39.5	21.2	23.4	15.9	78.4	61.4	38.0	22.1
1965-1966	31.1	31.7	18.9	18.3	62.2	56.8	37.9	28.2
1966-1967	30.6	25.2	21.1	23.1	83.2	85.3	64.3	41.2

Source: Computed from data in Appendix Tables A-10 and A-11.

Price Behavior

As we turn from measurement of production and utilization to analysis involving prices, the data problems become more serious and limiting. For example, no public agency maintains any systematic continuous series pertaining to retail prices or prices received by processors for the frozen product. Even at the farm level, the U.S.D.A. published price or average value series combine sales for fresh market and processing uses. To circumvent some of these problems--i.e., to develop at least the minimal series essential for analysis--we have drawn on unconventional sources for much of our price data. These will be described in the course of the presentation.

Figure 8 shows the movement of average grower prices from 1949--the first year that such data were published--until 1968.[1/] Note the general downward movement of California prices until 1958 and then, coinciding with the establishment of the Brussels Sprouts Marketing Program, a substantial upward trend. Meanwhile, for reasons not entirely clear, prices in New York, the only other region for which such data are available, continued to move sharply downward. It is possible that some of the New York change is due to the effect of differences in fresh and frozen product mix on average prices (a shift from fresh to frozen outlets) and perhaps some variation in the method of reporting, but we have no clear indication of this. Even allowing for this possibility, it seems evident that New York prices have declined substantially relative to California.

For information concerning prices received by freezers we have turned to the monthly quotations given in the trade magazine, *Quick Frozen Foods*.[2/] This is the longest series and appears to be the most consistent of available

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1/ Data for Figure 8 are given in Appendix Table A-18. The California Crop and Livestock Reporting Service tabulates, but does not publish, separate grower price series for the fresh and frozen market quantities. We have been permitted to use this information in our analysis but are not authorized to publish it since it is felt that it might reveal individual operations.

2/ See Appendix Table A-13 for complete reference.

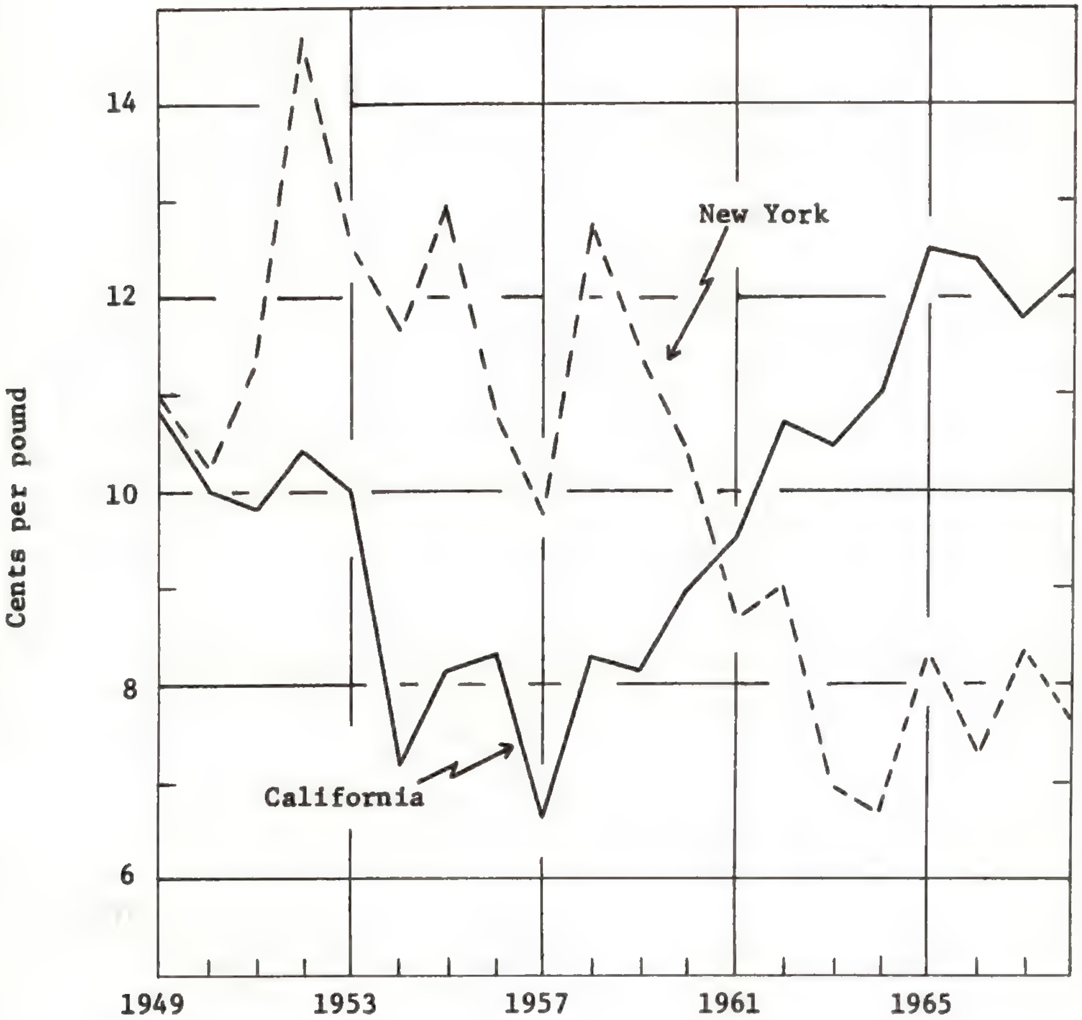

FIGURE 8

Average Price per Pound Received by Growers of Brussels Sprouts for all Forms of Sale, 1947-1968

trade data. While these list prices may differ some from actual transaction prices, they provide a measure of general movement and relationships over time.

Figure 9 shows the pattern of monthly price quotations for the period 1958-1967. These prices are commonly given as a range and the values plotted in Figure 9 are midpoints of the ranges. Actual data, including figures for years prior to 1958, are given in Appendix Tables A-13 to A-16.

Since the mid-1950's, the price quotations for institutional size containers have been given by individual sprout size class, measured in terms of count of sprouts per package. Prices for the small sizes, those with the largest count per pound, have been consistently above the medium prices which in turn have been above the large size prices. The magnitudes of these differences have varied somewhat in time.

No sprout size breakdown is given for retail container quotations. We believe they refer primarily to medium sizes, this being the most common, but there is no way to be sure. The retail container prices have also been more variable than the institutional quotations. This may reflect either or both more rapid and realistic adjustments to actual market conditions or some variation in the size mix.

We have made a limited comparison between these list prices and actual transaction prices from 1961-1962 data obtained in our survey of freezers. Figure 10 shows these actual transaction prices in relation to the *Quick Frozen Foods* quotations.[1/] Actual average prices tend to compare rather closely with the quotations for institutional small and medium sizes. They are consistently below the large size quotations. The latter may be due in substantial part to the inclusion of some B grade in the average sample transaction prices whereas the quotation refers only to A grade.

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1/ Sample survey data are given in Appendix Table A-17.

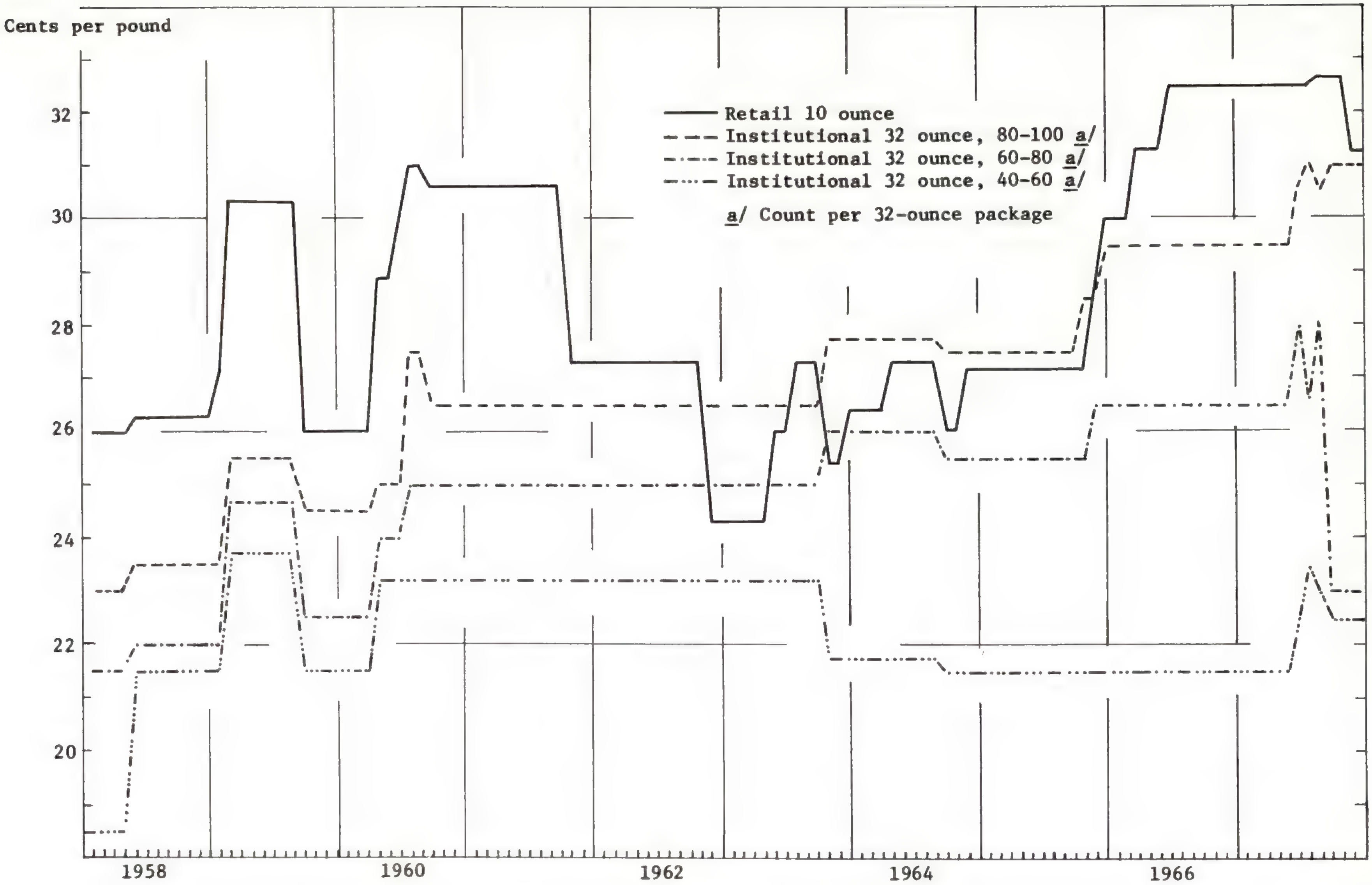

FIGURE 9

Midpoint Values of Monthly F.O.B. Freezer Price Quotations for California Brussels Sprouts, Grade A Quality, 1958-1967

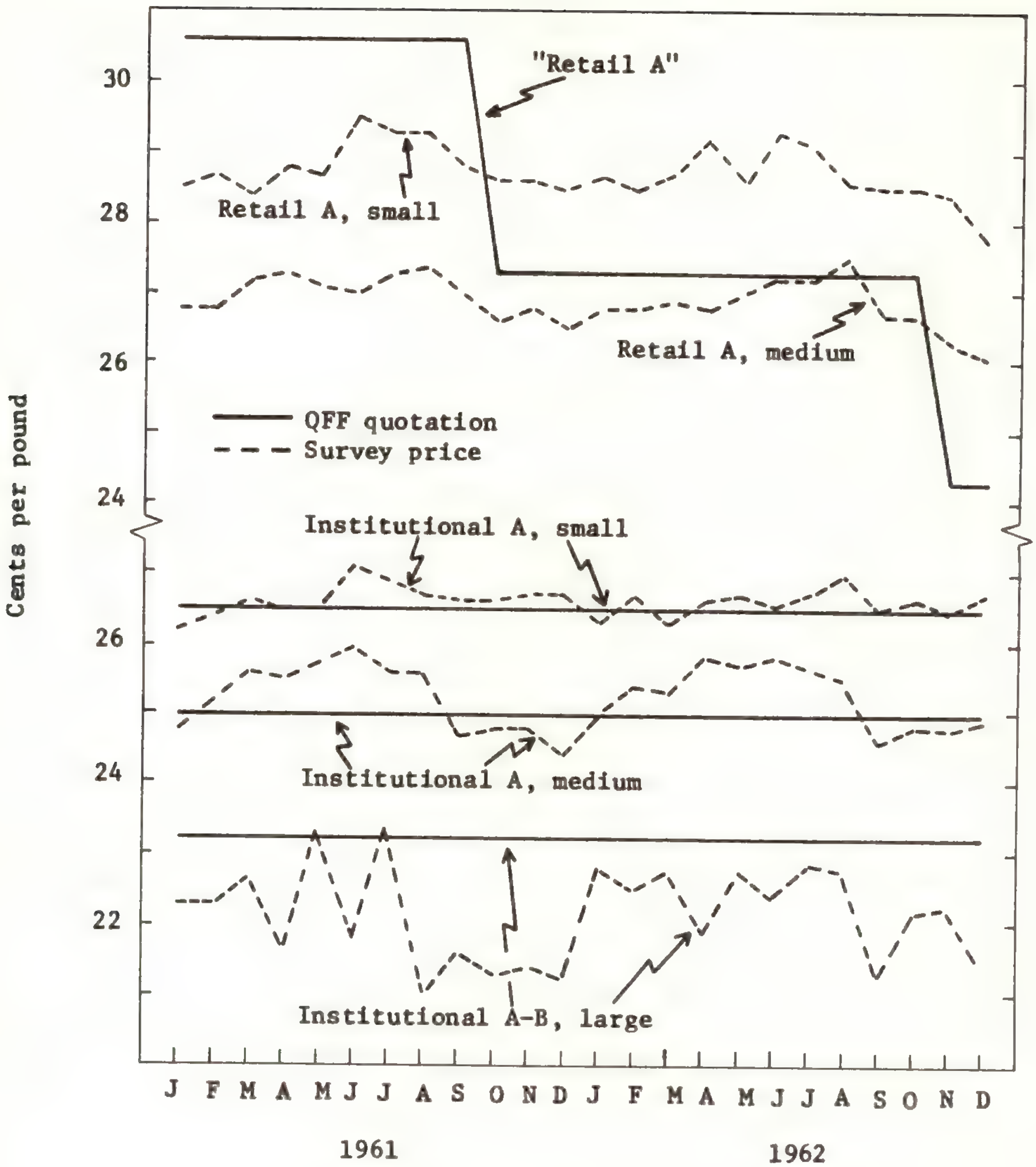

FIGURE 10

Comparison of Midpoint Values of Monthly QFF F.O.B. Freezer Price Quotations with Average Sales Prices Obtained in 1961-1962 Freezer Survey

Actual and list prices conform less closely for retail containers, although they fall in the same general range. It appears that the quoted price may have lagged behind the actual transaction prices in the early part of 1961 and then adjusted fairly well during most of 1962. It may be recalled also that the list prices are usually given as a range and the midpoint value may not always be an accurate reflection of the most prevalent price. While it would be helpful to have a longer period and wider range of variation for comparison, it appears that the list prices may be reasonably indicative of general levels and movements of prices for the commodity.

Figure 11 shows the more general movement of freezer and grower prices for the period 1947-1968.[1/] The annual freezer prices are simple averages of monthly quotations for the crop year beginning September 1. For comparative purposes, grower prices have been expressed in terms of equivalent frozen product rather than initial raw product weight. The grower prices include returns from fresh market sales and thus only approximate the raw product cost of freezers. While grower and freezer prices show the same overall movement, the year-to-year variations are less close. This is to be expected since, in addition to the fresh market influence, the grower prices for freezing and f.o.b. freezer prices for the final product are determined under different conditions. Grower prices are determined by the interaction of uncertain demand expectations of processors with grower supply, while f.o.b. prices are determined by actual final product demand and stock levels.

Consumption Patterns

Figure 12 shows the level and changes in U.S. per capita disappearance of Brussels sprouts from domestic production. These are not per capita consumption figures in strict terms since they make no adjustments for exports and imports. However, they are somewhat more detailed with respect to the fresh component than the highly rounded U.S.D.A. per capita

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1/ See Appendix Table A-18 for data.

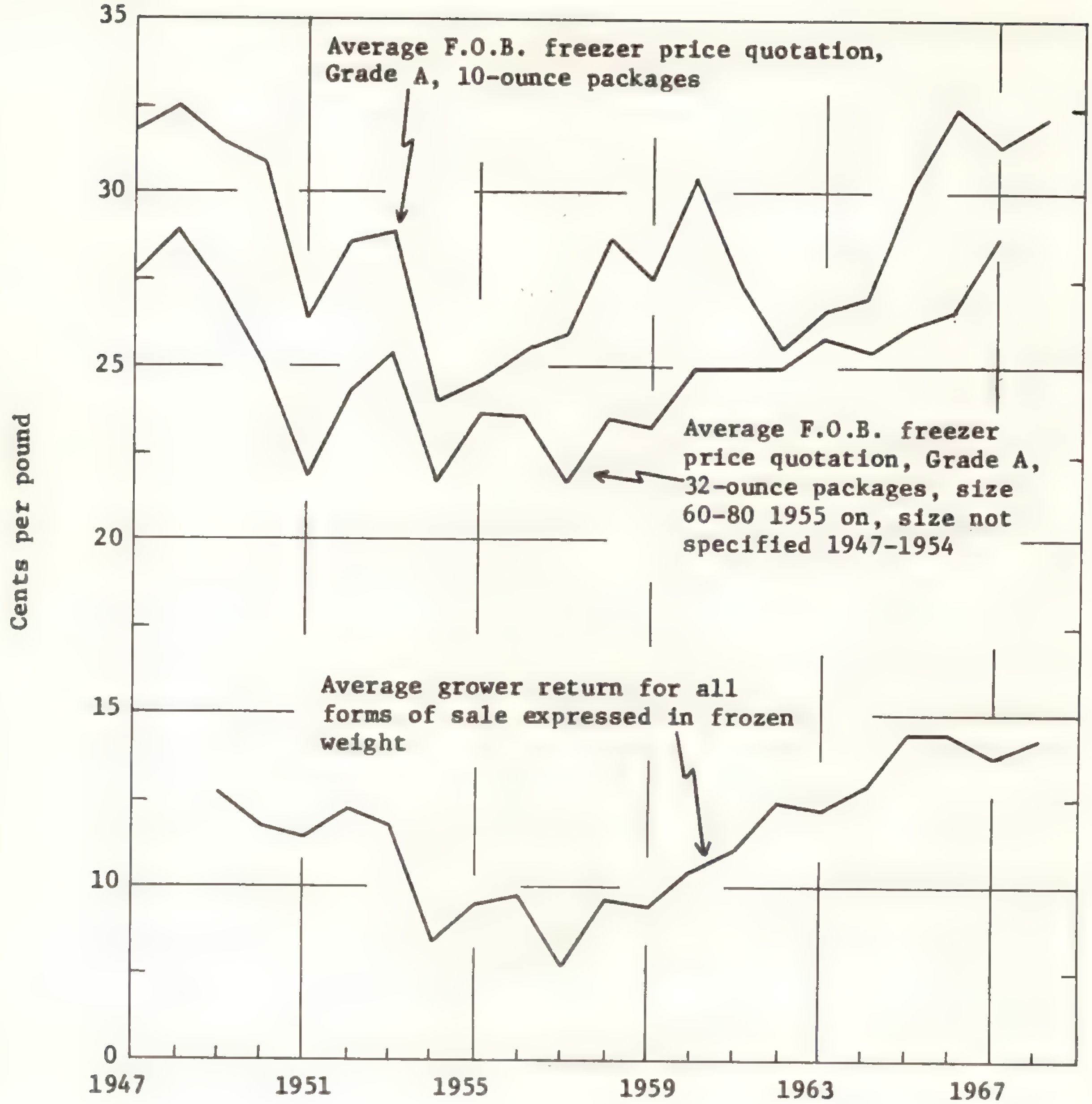

FIGURE 11

Changes in Freezer Price Quotations and Average Grower Prices for California Brussels Sprouts, Crop Years 1947-1968

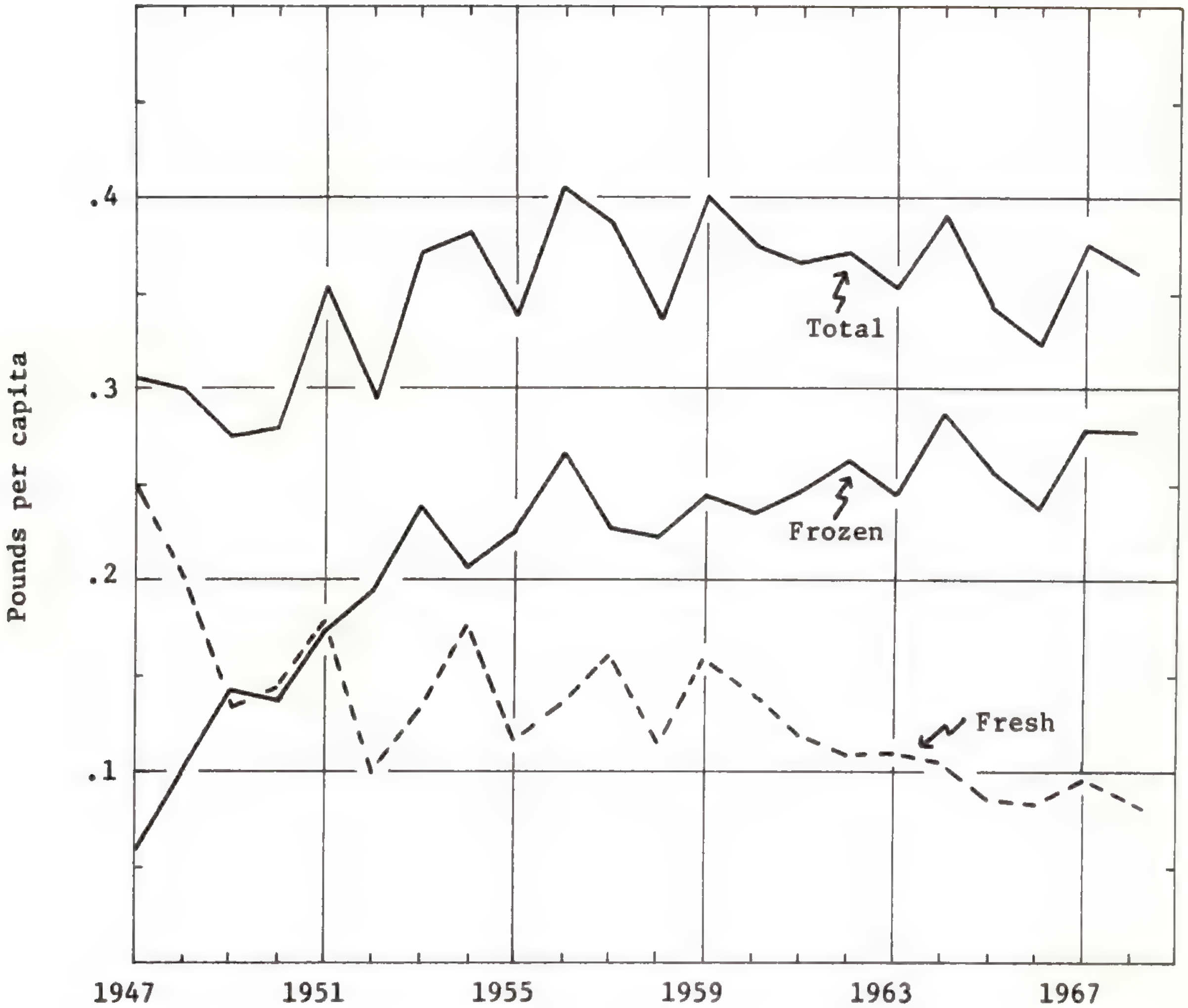

FIGURE 12

United States per Capita Disappearance of Brussels Sprouts from Domestic Production, 1947-1968

consumption data and therefore much more useful for purposes of economic analysis. There is no clear trend in total per capita disappearance of Brussels sprouts since the late 1950's, although if we look only at the 1960's, there appears to be a slight downward shift. During this period, per capita disappearance of the frozen component continued to move slowly upward, while per capita fresh consumption declined. Inclusion of fresh imports from Mexico (see Appendix Table A-12) would increase the recent levels of fresj per capita consumption but would not be sufficient to offset fully the fresh decline.

Figure 13 shows the levels and changes in per capita consumption of all fresh, frozen, and canned vegetables in the United States for the period since 1947. In a later section we shall attempt to measure statistically the way in which the several consumption and other demand influencing variables have been related to prices received by growers and processors of Brussels sprouts.

Production and Processing Costs

Table 5 gives sample costs of producing Brussels sprouts in California from multiple harvest varieties with yields and input prices at typical levels for about 1965. The figures were prepared by Agricultural Extension Service staff working with commercial producers and are indicative of typical industry experience but are not actual averages in a statistical sense. Costs in Table 5 do not include returns to management.

Table 6 shows sample costs to produce the Jade Cross variety with a single harvest by machine as of 1967. With this method, yields appear to be much lower, but so are harvest costs. Whether this results in lower or higher cost per pound cannot be determined by direct comparison of Tables 5 and 6 because of differences in assumed wage rates, power and material costs, management income, and a different sample of growers. A rough allowance for these differences brings the per pound cost of the two methods much closer together--perhaps only one-half cent difference.

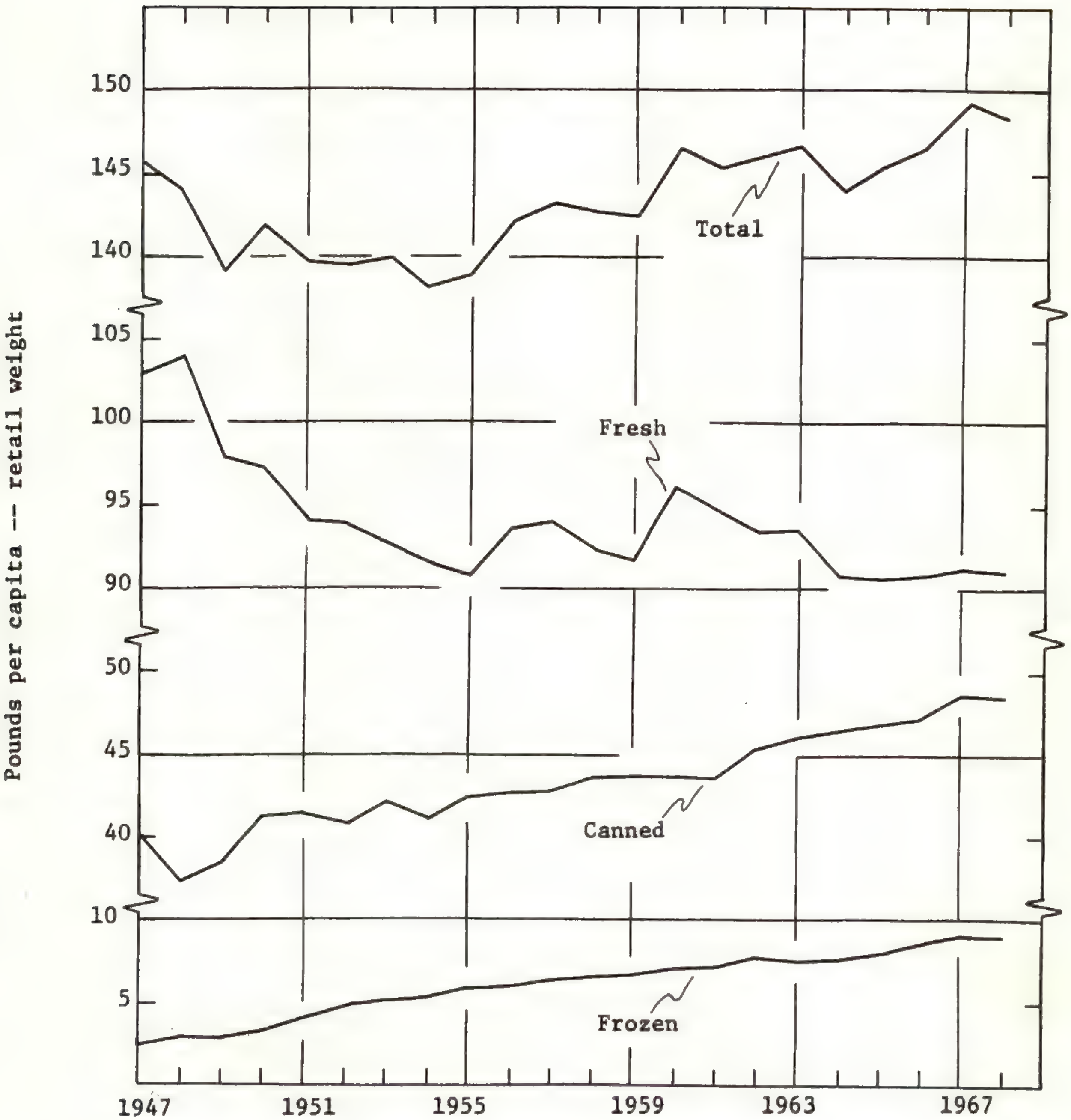

FIGURE 13

Changes in United States Civilian Per Capita Consumption of Fresh, Canned, and Frozen Vegetables, 1947-1968

TABLE 5

Sample Costs to Produce Brussels Sprouts in San Mateo County in 1965[a/]
(multiple harvest varieties)

Operation	Hours per acre	Cash and labor cost per acre: Labor	Fuel and repairs	Materials: Kind and quantity	Cost	Total
Cultural Costs						
Land preparation	6.0	$ 12.42	$13.80			$ 26.22
Growing plants	.5	.81		Seed, fertilizer, soil fumigation, insecticides	$ 13.00	13.81
Pulling plants	12.0	19.32				19.32
Setting plants by machine-6M	6.0	10.12	2.00			12.12
Cultivate	4.0	8.28	4.40			12.68
Hoe and weed	6.0	9.66				9.66
Irrigate	13.0	20.93	1.00	Power to pump (2 pumps)	14.00	35.93
Fertilize 2M	4.0	7.36	2.20	1500 lbs. 10-10-10	46.50	56.06
				5 T manure applied	42.50	42.50
				3 shots N in irrig. water	15.00	15.00
Pest Control						
Spray 2X contract				Guthion	15.00	15.00
Spray 2X	2.0	4.14	4.50	Systox	10.00	18.64
Spray 6X	6.0	12.42	13.50	Parathion, phosdrin	45.00	70.92
Dust 4X	3.0	6.21	3.90	Parathion	16.00	26.11
Fumigation (contract)				D-D or Telone	60.00	60.00
TOTAL	62.5[b/]	111.67	45.30		277.00	433.97
Harvest Costs						
Pick	260.0	418.60				418.60
Haul, clean, trim	73.0	117.53		Trucking, bin rental	22.75	140.28
TOTAL	333.0[c/]	536.13			22.75	558.88
Cash Overhead						
Misc., office, etc.						49.64
Promotion, research						12.00
Rent (cash)						80.00
TOTAL						141.64
TOTAL CASH COST						1,134.49
Depreciation on tenant's field and irrigation equipment						101.35
Interest on tenant's field and irrigation equipment						23.38
TOTAL COST PER ACRE						1,259.22
Cost per pound @ 13,000 lb. yield						9.09¢
Cost per ton						193.73

a/ Based on the following values for labor, tractor costs, and yields: Labor: Skilled - $2.07 per hour; Common - $1.61 per hour, Tractors: 40 H.P. C.D. = $1.50 per hour; 30 H.P. wheel tractor = $.95 per hour, Yield: 6-1/2 tons per acre or 13,000 lbs, spacing - 26" x 36".

b/ The 62.5 hours of cultural labor are made up of 38.5 hours of common and 24.0 hours of skilled labor.

c/ The 333 hours of harvest labor is all common.

Source: Parsons, Philip, and R. H. Sciaroni, "Costs to Produce Brussels Sprouts at Various Yields and Labor Rates," University of California Agricultural Extension Service, San Mateo County, April 1965.

TABLE 6

Sample Costs to Produce Brussels Sprouts in San Mateo
and Santa Cruz Counties, 1967 a/
(single machine harvest method)

Operation	Hours per acre	Labor	Fuel & repairs	Materials: Kind and quantity	Materials: Cost	Total
Cultural Costs						
Land preparation	6.0	$ 12.90	$ 13.80			$ 26.70
Growing plants	.5	1.08		Seed, fertilizer, soil fumigation, insecticides, etc.	$ 20.82	21.90
Pulling plants	16.0	30.40				30.40
Setting plants by machine - 5M	12.5	24.37	3.75			28.12
Cultivate	4.0	8.60	4.80			13.40
Hoe and weed	6.0	11.40				11.40
Irrigate	16.0	30.40	1.00	Power to pump (2 pumps)	14.00	45.40
Fertilize (contract)				Side-dress 1,000 lbs. 10-10-10 (application cost $2.25/A.	40.90	40.90
				120 lbs. ammonium sulfate/A sprinkler applied	3.72	3.72
				120 lbs. ammonium nitrate/A sprinkler applied	6.00	6.00
Pest Control						
Fumigation (contract applied)				D-D or telone	60.00	60.00
Spray 1X (contract applied at $2.25/A)				Guthion	5.63	5.63
Spray 1X (contract applied at $2.25/A)				Guthion + parathion	6.85	6.85
Spray 1X (contract applied at $2.25/A)				Systox + thiodan	12.37	12.37
Spray 1X (contract applied at $2.25/A)				Phosdrin + thiodan	13.70	13.70
Spray 2X (contract applied at $4.50/A)				Systox	14.24	14.24
TOTAL	61.0	119.15	23.35		198.23	340.73
Harvest Costs						
Top	8.0	15.20				15.20
Tipping	15.0	28.50				28.50
Harvest (includes deleafing)	71.8	137.43	6.33			143.76
Cleaning, hauling	37.4	72.76	3.00			75.76
TOTAL	132.2	253.89	9.33			263.22
Cash Overhead						
Misc., office, etc.						30.18
Promotion, grading, research						21.25
Rent (cash)						70.00
TOTAL						121.43
TOTAL CASH COSTS						725.38
Management - 5 percent of 8,500 lbs. at 10.5¢ per lb.						44.63
Depreciation on tenant's field and irrigation equipment						134.04
Interest on tenant's field and irrigation equipment						29.78
TOTAL COST PER ACRE						933.83
Cost per lb. @8,500 lb. yield						10.99¢

a/ Based on the following values for labor, tractor costs, yields: Labor: Skilled - $2.15 per hour; Common - $1.90 per hour, Tractors: 40 H.P. C.D. = $1.50 per hour; 30 H.P wheel tractor = $1.00 per hour, Yield: 4-1/4 tons per acre, spacing 18" x 36", variety - jade cross.

Source: Welch, Norman, Philip Parsons, and R. H. Sciaroni, "Sample Costs to Produce Brussels Sprouts" (Single Machine Harvest Method), University of California Agricultural Extension Service, San Mateo and Santa Cruz counties, January 1968.

Continued experience with the single machine harvest method seems likely to lead to improved recovery rates and technical performance, with resulting lower costs per pound.

Data pertaining to costs of producing Brussels sprouts in other regions are not available.

Table 7 shows 1963 and 1964 average costs of freezing Brussels sprouts for 8 California firms producing 65 percent or more of the total pack in those years. These average accounting costs are slightly above the average f.o.b. price quotations for the same years (see Appendix Table A-18). Some caution should be exercised in drawing specific conclusions from this comparison since our price data are subject to error and the accounting costs may include somewhat arbitrary allocations of indirect costs. However, the figures suggest that Brussels sprouts may not have been an excessively profitable item for freezers in those years.

Data which show how production and processing costs have changed over time are quite limited. Figure 14 plots average cost values given in periodic sample surveys of the Agricultural Extension Service.[1/] The data pertain to costs of production in 1951-1952, 1956, 1962-1963, 1964-1965, and 1967-1968, the latter two given in more detail in Tables 5 and 6. The solid line drawn through the points shows the interpolated values we have used as indicators of cost levels in our economic analysis. While these are by no means precise measures of average industry costs, they approximate the overall movement. It seems clear that costs remained fairly stable during the decade of the 1950's and into the early 1960's. Increased factor prices were largely offset by higher productivity. Following the elimination of the Bracero Program, costs increased sharply and apparently have continued to rise since that time.

Figure 14 also gives an indication of changes in freezing costs, excluding the cost of the raw product. These values were obtained by applying a crude index of unit costs of freezing to shift the cost values

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1/ Data obtained from San Mateo County Farm Advisor, R. H. Sciaroni, (see Appendix Table A-21).

TABLE 7

Unit Cost of Freezing Brussels Sprouts, California
(24 10-ounce grade A), 1963 and 1964

Cost item	Weighted average 1963	Weighted average 1964
	cents per pound	
Receiving and preparation	2.952	2.889
Package, wrap, and case	1.570	1.438
Direct labor	4.522	4.327
Employee benefits	.693	.784
Freezing and 1st month's storage	.715	.714
Fuel, power, and water	.172	.186
Variable overhead	1.580	1.684
Packaging materials	2.734	2.345
Raw product	12.679	12.564
Raw product acquisition	.436	.379
Productive material	15.849	15.288
Variable manufacturing cost	21.951	21.299
Freight and loading	.214	.227
Cold storage	.742	.807
Direct selling expense	.837	.870
Specific selling costs	1.793	1.904
Total variable cost	23.744	23.203
Field expense	.161	.161
Superintendence and indirect labor	.514	.501
Factory burden	1.690	1.778
Financial, administrative, and general selling	1.882	1.886
Standby and programmed expense	4.247	4.326
Grand total cost per pound	27.991	27.529
Number of firms	8	8
Cases packed, specific item (thousands)	715	664
Pounds packed, Brussels sprouts (thousands)	30,963	30,856
Percent of national calendar year pack	73.2	65

Source: National Commission on Food Marketing, *Organization and Competition in the Fruit and Vegetable Industry*, Technical Study No. 4, June 1966, p. 245.

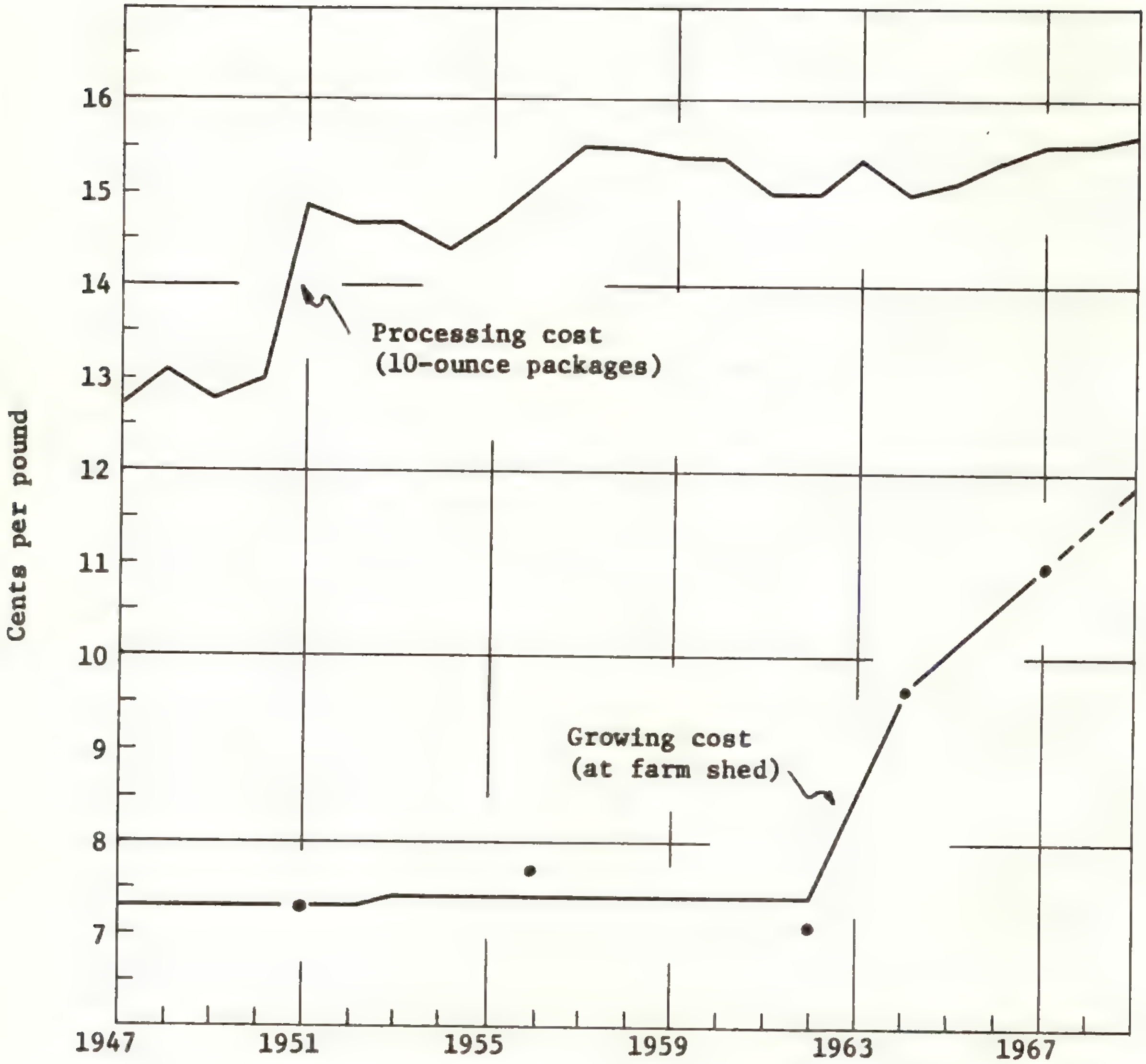

FIGURE 14

Indicators of Changes in Costs of Growing and Freezing California Brussels Sprouts, 1947-1969

given in Table 7[1] to other years. The index used is an aggregative index for all frozen vegetables so cost levels should be regarded as suggestive rather than precise measures of change. The figures indicate that freezing costs may have jumped sharply in the early 1950's, climbed gradually until the late 1950's, and then leveled off as increases in productivity offset increases in wage rate and other input prices. We shall make further use of this index in analyzing supply adjustment relationships.

THE STRUCTURE OF THE BRUSSELS SPROUTS ECONOMY

The first step in formulating an analytical model of the Brussels sprouts industry is to develop an understanding of the underlying economic structure. By "structure" we mean the nature of the relationships among prices, costs, and quantities produced or sold within and between market outlets and at different points in time.

The Brussels sprouts economy may be viewed as a combination recursive and simultaneous system of supply and demand equations. Conditions prevailing in one period influence decisions which, along with certain random elements, determine the production in the next period. Production then interacts with demand factors to determine prices, sales, and inventories which, along with the cost factors, again influence decisions which determine production in the next period and so on.

Graphic Representation

The general nature of this interrelated process is illustrated in Figure 15. To simplify the presentation, regional components have been excluded from the diagram. They are included in the mathematical formulation that follows. The major variables which measure performance and

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1/ See footnote to Table A-21 for source reference on index number computations. A similar type of cost index was computed for vegetable production but was deemed too aggregative to be applied directly to Brussels sprouts.

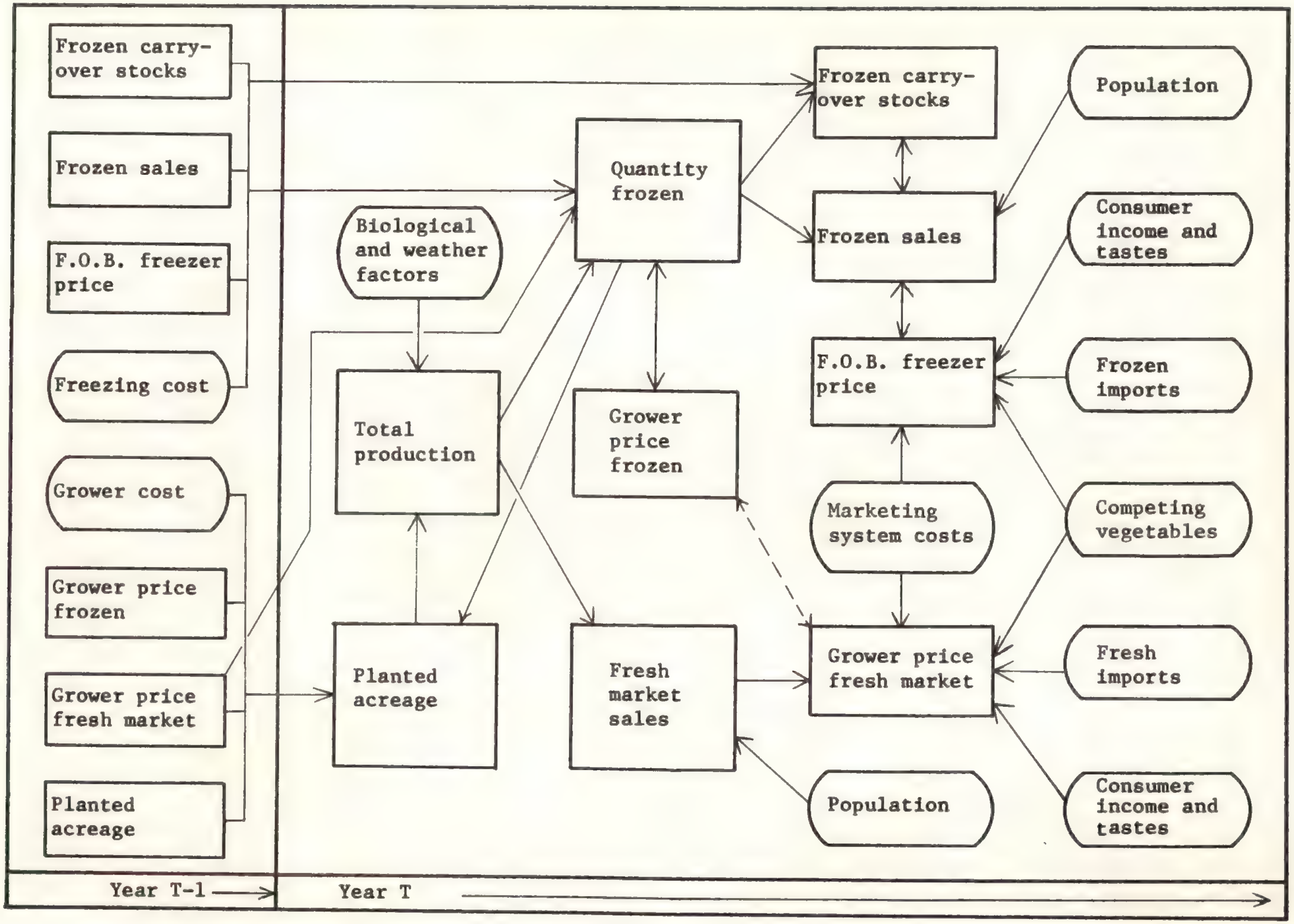

FIGURE 15

Structure of the Brussels Sprouts Economy

which are determined within the system are represented by rectangles. Variables which influence the behavior of the system, but whose values are regarded as determined by outside forces, are shown as ovals. Arrows indicate directions of major influence.

The bottom left part of the diagram lists the major variables whose values in year T-1 influenced planting decisions in year T. Planted acreage in T is also influenced by the quota established early in T under the Marketing Order Program for Frozen Brussels Sprouts. This is indicated by the arrow from the Quantity Frozen block to the Planted Acreage block. In describing the system prior to the establishment of the marketing order, this arrow might be deleted, but it seems reasonable that informal advance contacts among growers and freezers regarding quantities expected to be frozen might have affected the acreage planted. With acreage thus determined, total production is determined by biological and weather factors which influence yield.

The division of the total production between fresh and frozen outlets is determined by interaction of the demand of processors for the raw product and the growers' willingness to supply Brussels sprouts for freezing at various raw product prices. The level of processor demand is determined by market and cost expectations which are influenced mainly by experience in year T-1 (upper left part of diagram). The growers' willingness to commit Brussels sprouts to freezing at given prices is influenced by the level of costs and their expectations concerning the fresh market alternative. At the time the allocation decisions must be made, the level of fresh market demand is not well known and expectations for this market are based primarily on past price experience. Although the frozen outlet apparently is the preferred market for California growers, the existence of the fresh alternative means that increased allocations to freezing may require higher grower prices for processing Brussels sprouts to induce a shift in allocation. The joint nature of this allocation process is indicated by the two-way arrows between the Quantity Frozen and Grower Price Frozen blocks.[1/] The broken

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1/ We shall argue that the economic structure underlying the allocation process was not altered with the establishment of the Brussels Sprouts Marketing Program except to shift the level of the grower frozen supply allocation curve somewhat downward.

arrow between fresh and frozen market grower prices suggests a more limited current interaction between the two outlets.

Since storage of fresh Brussels sprouts is not possible, all quantities allocated to this outlet are marketed immediately and this--along with imports, consumer income and tastes, levels of competing vegetables, population, and marketing system cost--determines the grower-shipper price. The quantity of sprouts frozen, does not directly determine frozen sales since freezers have the option of storing the product until the next season. Thus, frozen sales, stocks at the end of year T, and f.o.b. freezer prices are all determined simultaneously as indicated by the two-way arrows.

Outline of the Structural Model

To provide a quantitative base for economic analysis, the system described above must be given specific mathematical form.1/ The model formulated consists of 16 equations and 16 endogenous variables (variables whose values are predicted by the model), plus 11 nonstochastic exogenous variables (values determined outside the model or taken as given in the analysis). Six of these equations are classed as behavioral relationships with parameters (coefficients) to be estimated statistically. The remaining equations consist of technical relationships or definitional statements necessary to describe the complete system. They are referred to as identities. The 16 types of relationships are listed and the variables identified in Table 8.

Equations 1, 3, 4, 5, 11, and 12 of Table 8 are behavioral relationships (identified by the empirical equation numbers in parentheses). Equations 1, 3, and 5 interact simultaneously to determine annual California production of Brussels sprouts, California grower prices for frozen sprouts, and the allocation of production between fresh and frozen outlets. For reasons to be explained, the fresh market allocation is determined residually by 6 and then Equation 4 determines the price received by California growers for quantities allocated to the fresh market.

1/ The nontechnical reader may prefer to skip directly to the summary of the model presented at the beginning of the section on Simulation of the Brussels Sprouts Economy.

TABLE 8

Reader's Guide to the Structural Model

I. Structural Relationships

Type of relationship[a/]	Variables involved (exogenous variables are in parentheses)
A. Farm Production	
1. California acreage, (1A)	A_{ct}, P_{gct}, Q_{pct}, (L_t), (v_{1t})
2. California production (Other region production treated as exogenous)	$Q_{ct} = (B_{ct})A_{ct}$ (Q_{pot}), (Q_{fot})
B. Farm Level Demand and Raw Product Allocation	
3. California freezer demand for raw product, (12A)	Q_{pct}, P_{pct-1}, P_{gpct}, D_{pct-1}, D_{pust-1}, S_{ust}, (C_{pct-1}), (L_t) (v_{7t})
4. California fresh market demand, (13A)	P_{gfct}, X_{bft}, X_{bpt}, (X_{vt}), (F_t), (v_{8t})
5. California frozen allocation, (14A)	Q_{pct}, P_{gpct}, P_{gfct-1}, P_{gfct-2}, D_{pct-1}, (C_{gct}), (L_t), (v_{9t})
6. California fresh market allocation	$Q_{fct} = Q_{ct} - 1.172\ Q_{pct}$
7. U.S. fresh market sales	$Q_{fust} = Q_{fct} + (Q_{fot})$
8. U.S. fresh per capita sales	$X_{bft} = Q_{fust} \div (N_t)$
9. U.S. frozen pack	$Q_{pust} = Q_{pct} + (Q_{pot})$
10. California average farm price	$P_{gct} = \left[\dfrac{1.172\ Q_{pct}}{Q_{ct}}\right] P_{gpct} + \left[\dfrac{Q_{fct}}{Q_{ct}}\right] P_{gfct}$

(Continued on next page.)

Table 8 continued.

Type of relationship[a/]	Variables involved (exogenous variables are in parentheses)
C. <u>Frozen Product Demand and Inventory Allocation</u>	
11. Demand facing freezers, (16A)	P_{pct}, X_{bpt}, X_{bft}, (X_{vt}), (F_t), (R_t), (u_{1t})
12. Sales allocation of freezers, (17A), (18A)	D_{pust}, Q_{pust}, S_{ust}, D_{pust-1}, P_{pct}
13. U.S. per capita sales, frozen	$X_{bpt} = D_{pust} \div (N_t)$
14. Inventory allocation of freezers	$S_{ust+1} = Q_{pust} + S_{ust} - D_{pust}$
15. California share of U.S. frozen sales	$D_{pct} = \frac{Q_{pct}}{Q_{pust}} \cdot D_{pust}$
16. Other region share of U.S. frozen sales	$D_{pot} = \frac{Q_{pot}}{Q_{pust}} \cdot D_{pust}$

II. <u>Variable Identification</u>[b/]

A_c = acres of Brussels sprouts planted in California (end.) Table A-1.

P_{gpc} = average price received by California growers for Brussels sprouts for freezing (end.). (Not included in appendix tables because of publication restrictions.)

P_{gfc} = average price received by California growers for fresh market Brussels sprouts (end.). (Not included in appendix tables because of publication restrictions.)

P_{gc} = average price received by California Brussels sprouts growers for all forms of sale (end.) Table A-18.

C_{gc} = representative cost of growing Brussels sprouts in California (ex.) Table A-2.

v_i = term to account for unexplained disturbances due to the effects of individually minor variables ($i = 1 \ldots 7$) (ex.).

(Continued on next page.)

Table 8 continued.

II. Variable Identification[b]

B_c = yield per acre of Brussels sprouts in California (ex.) Table A-2.

Q_c = total production of California Brussels sprouts (end.) Table A-3.

Q_o = total production of Brussels sprouts in regions other than California (ex.) Table A-3.

Q_{pc} = quantity of Brussels sprouts frozen in California (end.) Table A-5.

Q_{po} = quantity of Brussels sprouts frozen in regions other than California (ex.) Table A-5.

Q_{pus} = total United States frozen pack of Brussels sprouts (end.) Table A-5.

Q_{fc} = quantity of fresh market Brussels sprouts produced in California (end.) Table A-3.

Q_{fo} = quantity of fresh market Brussels sprouts produced in United States regions other than California (ex.) Table A-3.

Q_{fus} = United States production of fresh market Brussels sprouts (end.) Table A-3.

L = A dummy shift variable to allow for possible changes in level of supply response or allocation with the establishment of the Brussels Sprouts Marketing Program. L = 0 prior to 1958; L = 1 from 1958 (ex.). (In a first difference equation, $\Delta L = 1$ in 1958; $\Delta L = 0$ in all other years.)

S_{us} = United States cold storage holdings of Brussels sprouts on August 31 (end.) Table A-22.

D_{pc} = quantity of California frozen Brussels sprouts sold (disappearance), August 1 - July 31, (end.)[c] Table A-22.

D_{po} = quantity of other region frozen Brussels sprouts sold (disappearance), August 1 - July 31, (end.)[c] Table A-22.

D_{pus} = United States quantity of frozen Brussels sprouts sold (disappearance), August 1 - July 31, (end.)[c] Table A-22.

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Table 8 continued.

II. Variable Identification[b/]

P_{pc}	= average f.o.b. California freezer price for Brussels sprouts, grade A, 10-ounce packages (end.) Table A-18.
C_{pc}	= cost of freezing Brussels sprouts in California excluding raw product cost, 10-ounce packages (ex.) Table A-21.
u_i	= term to account for unexplained disturbances ($i = 1 \ldots 3$) (ex.).
N	= United States 50 state population including armed forces overseas as of January 1 of crop year, millions (ex.) Table A-20.
X_{bp}	= $D_{pus} \div N$ = United States per capita disappearance of frozen Brussels sprouts, pounds (end.) Table A-19.
X_{bf}	= $Q_{fus} \div N$ = United States per capita disappearance of fresh Brussels sprouts, pounds (end.) Table A-19.
X_v	= United States per capita total vegetable consumption, pounds retail weight, calendar year (ex.) Table A-19. (Two-year averages used in the empirical analysis to convert to an approximate crop year basis.)
R	= proportion of United States homes with refrigerators (ex.) Table A-20.
F	= United States per capita total food expenditures expressed as an index, 1957-1959 = 100, (ex.) Table A-20.
Y	= $R \cdot F$ (ex.) Table A-20.

a/ The numbers in parentheses designate behavioral relationships keyed to the relevant structural and empirical equations that follow. The remaining equations are identities.

b/ The variables are listed approximately in the order in which they appear in the model development. The abbreviation end. in parentheses means that the variable is classed as endogenous; ex. indicates an exogenous variable. The table numbers refer to appendix tables containing the actual data series. The subscript t (or t-1) attached to a variable indicates the particular year to which it applies. All values pertain to the crop year beginning September 1 unless otherwise indicated. A

(Continued on next page.)

Table 8 continued.

superscript * is used to indicate a planned rather than actual value. Quantities are measured in million pound units unless otherwise specified and prices and costs are in cents per pound. The number 1.172 in Equations 6 and 10 is a factor for converting from frozen to raw product weight.

c/ The reason for using August 1 - July 31 disappearance rather than September 1 - August 31 is explained in Appendix B.

Because of incomplete, nonexistent, or uncertain price and cost data for regions other than California, we were not able to develop comparable supply and production allocation equations for these areas. Therefore, we have treated quantities frozen and marketed fresh in other regions as exogenous variables, with alternative trend projections considered in the final simulation experiments. Total United States quantities are determined by adding "other region" quantities to endogenous California quantities as indicated by Identities 7 and 9.

Relationships 11 and 12 form another simultaneous subsystem which determines the price received by freezers and the total U.S. quantity of frozen product marketed. The quantity carried in inventory from one season to the next is then determined by the identity relationship 14. Regional shares of total sales are determined by Identities 15 and 16.[1/]

With this outline of the model, we turn now to the development of the specific mathematical forms of the behavioral relationships. This is followed by a section dealing with empirical estimation of these equations. The entire final model is summarized at the beginning of the section on simulation experiments.

Farm Production

The farm production component of the Brussels sprouts model involves two types of relationships--an equation which predicts acreage adjustments and another which converts acreage into production. This section develops the reasoning behind the specific forms which these equations assume in the model.

Grower planning for California Brussels sprouts production may be thought of as a two-stage decision process. Preliminary planning begins in the early spring months with the preparation of seed beds and the growing of transplants. During May and June the land is prepared for

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1/ Since cold storage reports do not identify where the product was produced it is not possible to determine actual sales by regions. This value is approximated by assuming that regional sales are proportional to regional shares of total frozen pack. Regional shares of storage stocks, if required, would be determined in a similar manner.

planting and the plants set out. In late May or June a market quota is established for Brussels sprouts for freezing, at which time growers may modify their original plans. In most years the quantity actually frozen has been very close to the quota. Prior to the establishment of the market order program there was, of course, no announced quota to guide decisions. However, informal contacts between growers and freezers could well have provided some advance indication of quantities expected to be frozen. Consequently, the level of frozen pack has been included as a variable influencing planted acreage before, as well as after, the establishment of the Brussels Sprouts Marketing Program.

In making their preliminary planting decisions, growers are presumed to examine their past price and cost experience for both Brussels sprouts and the alternative crops that might be produced on their land. Favorable price-cost experience with Brussels sprouts leads to an increase in acreage relative to the previous year; less favorable experience to a decrease. The amounts by which production plans are altered for different levels of past profit experience depends on the manner in which producer expectations are formed and applied. For example, if growers always believed that this year's price would prevail the following year, they would tend to produce either "too much" or "too little."[1/] If they felt others in the industry were behaving in a similar manner, they might modify their price expectations. Price expectations might also be modified based on errors in previous expectations, although attempts by economists to give explicit form to such considerations in formulating supply models have so far met with only modest success, at best.[2/]

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1/ This is the well-known "cobweb" phenomenon which has played as important role in explaining adjustment processes in agricultural industries. See, for example, Waugh, Frederick V., "Cobweb Models," *Journal of Farm Economics*, Vol. 46, No. 4, November 1964, pp. 732-750.

2/ Nerlove groups models of expectation formation in three classes: extrapolative, adaptive, or rational. For a discussion of these approaches see Nerlove, Marc, "Time-Series Analysis of the Supply of Agricultural Products," Chapter 2 of *Agricultural Supply Functions* (edited by E. O. Heady, *et al.*), Ames: Iowa State University Press, 1961.

The aggregate influence of alternative crop returns on Brussels sprouts supply response is particularly difficult to measure. Discussions with California growers suggest that other vegetables such as broccoli are not regarded as good alternatives on Brussels sprouts land. Other crop possibilities appear variable among farms and provide little basis for aggregate prediction. Their effects, if any, thus show up in the disturbance or error term of the supply equation.

<u>Acreage Adjustment in California</u>

With these considerations, the yearly change in acreage is related to past changes in profitability (ΔM_{gct-1}), changes in the size of the frozen pack ($Q_{pct} - Q_{pct-1}$), a variable associated with the Brussels Sprouts Marketing Program (ΔL_t) and a random disturbance term (v_1), which accounts for the effects of omitted factors.

$$(1) \quad A_{ct} - A_{ct-1} = b_{10} + b_{11}\Delta M_{gct-1} + b_{12}(Q_{pct} - Q_{pct-1}) + b_{13}\Delta L_t + v_1$$

where

$$\Delta M_{gct-1} = (P_{gct-1} - C_{gct-1}) - (P_{gpct-2} - C_{gct-2})$$

and ΔL_t = 1.0 in 1958; zero for all other years.

The variable L_t is a dummy factor introduced to allow for the possiblity that the establishment of the Brussels Sprouts Marketing Program in 1958 may have affected the level of grower acreage response.

This model involves an element of "extrapolative" expectations. Past changes in prices and costs are extrapolated by growers into expectations of future net returns. However, there is no explicit assumption concerning the relation of expected prices to actual past prices or errors in past expectations.[1/]

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1/ Other equation forms were also investigated. For example, changes in acreages and production were expressed in relative terms rather than first differences. The discussion and presentation is limited in all cases to the algebraic forms which proved most satisfactory in the final empirical analysis.

Total Production in California

Total production (Q_{ct}) is identically equal to acreage (A_{ct}) multiplied by yield (B_{ct}); or

$$(2) \quad Q_{ct} = B_{ct}A_{ct}.$$

Yield per acre is treated as an exogenous variable (values taken as given or projected) in this analysis.

Farm Level Demand and Raw Product Allocation

This section develops four major relationships; the first relates to freezer demand for raw product, the second to demand for fresh sprouts, and the third and fourth to the allocation between fresh and processed sales.

Freezer Demand for Raw Product

The quantity of Brussels sprouts which freezers desire to process in a particular year is determined by their expectations as to (a) future sales, prices, and costs of processing the final product; (b) inventory levels; and (c) the price to be paid to growers for the raw product. To place the adjustment process in a mathematical framework suitable for statistical analysis, we first specify an identity relationship which partitions planned pack into the sum of planned sales and planned adjustments in levels of stocks carried from one period to the next.

$$(3) \quad Q^*_{pt} = D^*_{pt} + S^*_{t+1} - S_t.$$

Since the model to be formulated applies conceptually to all areas we shall, for convenience, omit the regional subscripts (i.e., c or o) in the development. For purposes of comparing with the outline in Table 8 and the later empirical analysis, a subscript c should be added to all price, cost, and quantity variables in Equations (3) through (12).

None of the starred variables is observable. To develop a quantitatively measurable model, we relate the unobservable to observable variables and random disturbances and substitute them in (3).

Planned pack.--It seems reasonable to assume that actual pack may be close to or identical with the pack finally planned or desired by processors. Minor deviations may occur as a result of weather or other random operational factors beyond the control of management. Planned pack thus may be expressed as:

$$(4) \quad Q^*_{pt} = Q_{pt} + v_{2t}.$$

Planned sales.--The manner in which freezers plan production adjustments from one period to the next is conditioned by the competitive structure of the industry. The fewness of the Brussels sprouts freezers suggests a somewhat oligopolistic structure, with each freezer conscious of the actions of his competitors and his own market share. As a working hypothesis we shall assume that planned or desired sales of each freezer are determined by first establishing a target price and then adjusting production by an amount thought to be necessary to achieve this target price, with allowance for expected adjustments of competitors. The firm's target price is defined as the sum of expected average unit costs of freezing, cost of the raw product, and some constant representing desired or target level of profit margin. The desired profit margin could also be expressed as a proportion of total cost, but it is simpler not to do so in this case. The target profit margins may vary among firms, and over time with market conditions.

The average industry target price can be represented by (or expressed as a function of) expected average industry unit freezing cost (C^*_p), the raw product cost, which is essentially the same for all freezers, an average target profit margin, and a random term reflecting period-to-period variations not accounted for by the listed variables. Algebraically,

$$(5) \quad P^*_{pt} = C^*_{pt} + kP_{gpt} + b_{20} + v_{3t}$$

where k is a factor for converting from frozen product to raw product weight. The term b_{20} is the desired or target profit margin, which we shall treat

as constant although it might vary as a function of past levels of profitability or the state of business conditions. A dummy variable (L) may be included to allow for a possible shift in the target profit margin with the establishment of the Brussels Sprouts Marketing Program. We shall assume that expected costs can be represented as C_{pt-1} plus some constant which may reflect the trend in cost or possibly some bias in our measure of cost. Thus, we may rewrite (5) as

$$(6) \quad P^*_{pt} = C_{pt-1} + kP_{gpt} + b_{30} + b_{31}L_t + v_{3t}.$$

The amount by which processors attempt to adjust production in view of the established target price depends on the manner in which they perceive the demand function for their product and the probable actions of their competitors. Presumably, the management of each firm forms some notion of the effect on the price of Brussels sprouts of changes in quantities of Brussels sprouts marketed, and the likely impact of changes in quantities of competing products, growth of population and income, and other outside factors which may affect the level of demand. They also have some notion about the likely behavior of competitors. Sales plans for the entire industry then are determined as the sum of these individual firm perceptions.

The aggregate processor perceptions of demand could assume any of several mathematical forms. After empirical explorations with a strictly linear equation, a constant percentage relationship, and a mixture of the two, we selected the latter on grounds of "best fit" and the need to derive a final equation form with properties most suitable for statistical estimation. The mixed form relates given absolute changes in prices to constant percentage changes in quantity of sales. The planned sales equation thus is as follows:

$$(7) \quad D^*_{pt} = D_{pt-1}\ [b_{40} + b_{41}\ (P_{pt-1} - P^*_{pt}) + v_{4t}].$$

The coefficient b_{41} reflects the composite of processor notions about the effects of quantity marketed on the price of Brussels sprouts, possibly modified by cautious attitudes or physical and financial restrictions on

rates of expansion. The latter, however, are assumed minimal in this analysis. Processor notions of the effects of competing products and other demand factors seem likely to be highly subjective and variable. Their influence is therefore reflected in the unexplained disturbance term, v_{4t} and in the trend coefficient b_{40}.

Substituting (6) into (7) gives

$$(8)\quad D^*_{pt} = D_{pt-1}\,[b_{50} + b_{51}(P_{pt-1} - C_{pt-1} - kP_{gpt}) + b_{52}L_t + v_{5t}]$$

where

$$b_{50} = b_{40} - b_{41}b_{30},$$

$$b_{51} = b_{41},$$

$$b_{52} = -b_{41}b_{31}, \text{ and}$$

$$v_{5t} = v_{4t} - b_{41}v_{3t}.$$

The form of Equation (8) has the advantage of linear simplicity and at the same time permits the absolute response to given price or cost changes to increase as the industry becomes larger. This seems appropriate when measurement encompasses the range from early development to maturity of the industry. Note that if P_{pt-1} is equal to expected cost of processing plus normal profit and raw product price in year t, the planned sales for t are the same as actual sales in t-1, except for the trend and random disturbance effects. Since b_{51} is positive, if the price in year t-1 exceeds the expected costs, processors will tend to increase planned sales; they decrease sales plans if last year's price was below expected costs.

Planned stocks.--Product inventories are necessarily carried from one production period to the next so as to keep the marketing "pipeline" full and as a buffer against or a consequence of errors in judging demand, weather effects, and other uncontrollable factors. The "normal" quantity of carryover may vary roughly as a proportion of the planned sales. Planned adjustments in levels of stocks held at the end of crop year t may be expressed as a linear function of the difference between normal stocks and the level of stocks at the beginning of the period. That is,

$$(9)\quad S^*_{t+1} - S_t = \alpha(\lambda D^*_{pt} - S_t) + v_{6t}$$

where

λ is the "normal" or desired carryover ratio and α is another constant.

If the industry decision makers were fully perceptive in their judgments, α would have a value of 1.0. The sum of individual inventory plans would call for an adjustment to the desired normal level, (λD^*_{pt}). Values of α below 1.0 would suggest some sluggishness in adjusting inventory levels while values greater than 1.0 would indicate a tendency to overreact--for processors give too much weight to current inventory levels in the adjustment process.[1/] It is possible that the value of λ may vary with the size of the industry and with taxes and interest rates. However, average carryover ratios have not changed appreciably with the growth of total sales and we have had limited opportunity to observe the effects of recent high interest rates. Consequently, we shall treat λ as though it were a constant in this analysis.

The final processor raw product demand equation.--Equations (4), (8), and (9) may now be substituted into (3) to eliminate the nonobservable variables and to obtain a function expressed entirely in terms of measurable quantities. First substituting (4) and (9) into (3) gives

$$(10)\quad Q_{pt} = D^*_{pt}(1 + \alpha\lambda) - \alpha S_t + v_{6t} - v_{2t}.$$

Now substituting (8) into (10), we obtain

$$(11)\quad Q_{pt} = (1 + \alpha\lambda)D_{pt-1}\,[b_{50} + b_{51}(P_{pt-1} - C_{pt-1} - kP_{gpt}) + b_{52}L_t + v_{5t}] - \alpha S_t + v_{6t} - v_{2t}.$$

1/ Alternatively α may be viewed as having a value of 1.0 but the level of S_t may be considered by processors in evaluating the potential level of demand during the forthcoming year, thus appearing as a variable in Equation (8). Relatively high or low values of S would be indicative of errors in judging demand during the past period and so would lead to some modification of anticipated demand levels in the next period. Either formulation leads to the same final form of freezer demand equation for raw product.

For estimation purposes, (11) may be expressed more conveniently as

$$(12) \quad \frac{Q_{pt}}{D_{pt-1}} = b_{60} + b_{61}M_t + b_{62}L_t + b_{63}\frac{S_t}{D_{pt-1}} + v_{7t}$$

where

$$\begin{aligned}
M_t &= P_{pt-1} - C_{pt-1} - kP_{gpt}, \\
b_{60} &= (1 + \alpha\lambda)b_{50}, \\
b_{61} &= (1 + \alpha\lambda)b_{51}, \\
b_{62} &= (1 + \alpha\lambda)b_{52}, \\
b_{63} &= -\alpha, \\
v_{7t} &= (1 + \alpha\lambda)v_{5t} + \frac{v_{6t} - v_{2t}}{D_{pt-1}}.
\end{aligned}$$

We shall assume that v_{6t} and v_{2t} vary approximately as random proportions of D_{pt-1}, thus eliminating D_{pt-1} as a factor in the total disturbance term. Therefore, v_{7t} is regarded as a random disturbance with zero mean and roughly constant variance.[1/]

Note that the value of λ is not identifiable (cannot be determined) by estimation of the parameters of (12). This is of no consequence as long as λ remains constant. The impact of a reduction in λ, as might occur with current very high interest rates, could be approximated by subtracting a constant from (12) equal to the amount of the reduction times the coefficient b_{63}. For example, if λ were 0.28 and decreased to 0.18, the constant $0.10(-b_{63})$ would be subtracted. This would leave the predicted pack unchanged for the level of $\frac{S_t}{D_{t-1}}$ reduced by a factor of 0.10.

Fresh Market Demand

By fresh market demand we mean the schedule of prices, received by grower-shippers, associated with various quantities placed on the market

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1/ A subscript c, to denote California, is added to each of the variables in our empirical estimates of (12). Note that since both S_c and D_c are computed as the same proportion of S_{us} and D_{us} (as explained in the outline of the model), $\frac{S_{ct}}{D_{ct-1}} = \frac{S_{ust}}{D_{ust-1}}$.

in particular time periods (or vice versa). Since the fresh product is not storable, the demand is derived directly from the demand of consumers, rather than indirectly through processor expectations as in the frozen outlet. Consumer demand may shift with population, income, sales of competing vegetables, shifts in taste, and the composite effect of a wide assortment of individually minor factors. Demand may also vary among regions, and by packages, sizes, and qualities of the basic commodity. The set of demand equations facing shippers in a particular producing region is obtained by subtracting transportation and marketing cost (which may also vary stochastically, with volume, and over time) from the consumer demand in each region and for each type of package and quality.

With several producing, and many consuming regions, the determination of the final set of regional shipping point prices involves a multimarket, multiproduct solution for each period. Since we lack the data required for estimating regional retail demand functions and measurement of marketing system cost, we shall abstract greatly from this complex structure and treat the changing effects of the marketing and distribution system simply as trend factors or a part of the unexplained disturbance. This permits us to measure demand in terms of a single equation directly at the grower-shipper level (or at the f.o.b. processor level in the case of the frozen product).

In formulating the demand equation we shall treat the California price as the dependent variable. Prices in other regions, if we knew them, could be expected to move closely with California prices, but probably at different levels, reflecting differences in transportation costs to markets. Since California shippers trade in national markets, the regional price is determined by demand variables pertaining to the total, rather than regional markets.

Use of price as the dependent variable stems from our argument that the fresh market quantity is determined mainly as a residual--i.e., quantities produced that are not allocated to freezing are marketed fresh. Fresh marketings, although endogenous in the total system, thus may be viewed as essentially predetermined with respect to the current fresh price. Sales of the frozen product, which are spread over the entire year, are

similarly regarded as affecting the current fresh market price, but are not themselves appreciably affected by this price. Further support for this argument is developed in the section on frozen product allocation and demand and in the section on empirical estimation.

With these considerations, the California shipping point price for fresh Brussels sprouts (P_{gfc}) is related to the U.S. per capita sales of fresh Brussels sprouts (X_{bf}), U.S. per capita sales of frozen Brussels sprouts (X_{bp}), per capita consumption of all other vegetables (X_v), U.S. per capita total food expenditures (F), and a random disturbance term. The equation form, with all variables measured in logarithms, (this expresses the relationship in percentage terms) is as follows:1/

$$(13) \quad P_{gfct} = b_{70} + b_{71}X_{bpt} + b_{72}X_{bft} + b_{73}X_{vt} + b_{74}F_t + v_{8t}.$$

Because of a lack of consistent import and export data extending over a period of years, per capita disappearance of frozen and fresh sprouts includes only quantities produced in the U.S., with no adjustment for exports. This does not appear particularly serious for frozen sprouts since the quantities imported are quite small, with net imports (imports minus exports) probably even smaller. The omission of fresh import data may be more significant in view of recent increases in shipments from Mexico. Unfortunately, we have no way of determining precisely how much of the fresh imports remain in the U.S., how much is transshipped to Canada, and how much of the fresh domestic production is exported. Since a major portion of the fresh imports is marketed when fresh domestic sprouts are in short supply, this omission may have a relatively minor affect on California fresh market prices. It could have a greater effect on the frozen sprouts, which are marketed throughout the year.

Per capita food expenditures (F) is used in place of income as an indicator of the general level of demand for food. The variable X_v allows for the aggregate effects of sales of competing vegetables on

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1/ A formulation linear in original values was also explored. The log form appeared to have a slight statistical advantage and only the results based on this form are reported.

the price of frozen Brussels sprouts.[1/] Such aggregation masks some of the separate influence of individual vegetables, such as fresh or frozen broccoli, cauliflower, or peas. It is necessary because of the impossibility of obtaining meaningful results with many individual competing product variables in a limited sample of observations.[2/]

Raw Product Allocation of Growers

To complete the farm level block of our model we need equations which determine the amount of sprouts growers desire to allocate to freezing and to fresh outlets. A key consideration in formulating the allocation equations is the information available at the time the allocation decisions are made. We noted in our initial discussion of the structure of the Brussels sprouts economy that quotas for freezing are established in late spring or early summer. At that time growers have little information about fresh market demand for the coming season. They do know how much was allocated to each outlet during the past season, the general level of current production costs, and the price received in the fresh market during past periods. Total current production is not known. For each set of values of these known variables there is a schedule of quantities growers desire to produce for freezing for various levels of prices paid by freezers for the raw product. The quantity allocated to the fresh market then is determined residually as the difference between final total production and the quantity frozen.

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1/ Variables F and X_v are available only on a calendar year basis. To be consistent with the supply components of our model, the other variables are expressed on a crop year basis. This means that the values of these exogenous variables coincide with the other crop year values for only a part of the crop year. This does not appear to create any significant problem for F. In the empirical analysis the competing products variable is expressed as two-year averages to convert more closely to crop year values.

2/ In an initial formulation, the variable X_v was split into three parts: X_f, per capita consumption of frozen vegetables; X_c, per capita consumption of canned vegetables; and X_r, per capita consumption of fresh vegetables--all measured in retail weight. This proved generally unsatisfactory because of high intercorrelation problems, principally between X_f and X_{bp}.

<u>Frozen allocation equation</u>.--With these considerations, the quantity that growers desire to produce for freezing is expressed as a function of the level of frozen sales during the previous year (D_{pct-1}), the current raw product price for freezing (P_{gpct}), the average fresh market price during the past two years ($\bar{P}_{gfct-1}$), the average cost of farm production (C_{gct}), and a shift variable (L_t) that allows for a more restrictive attitude with the establishment of the Brussels Sprouts Marketing Program in 1958. To facilitate simultaneous estimation, the dependent variable of the grower allocation equation is expressed in a form identical to the freezer raw product demand equation. The remaining variables enter linearly as follows:

$$(14) \quad \frac{Q_{pct}}{D_{pct-1}} = b_{80} + b_{81}P_{gpct} + b_{82}\bar{P}_{gfct-1} + b_{83}C_{gct} + b_{84}L_t + v_{9t}$$

where

$$\bar{P}_{gfct} = \frac{1}{2}(P_{gfct-1} + P_{gfct-2}).$$

At the time the frozen raw product allocations are made, the final grower price for freezing may still be somewhat uncertain. Our model assumes that there is sufficient exchange between growers and processors at the time the quotas are set for growers to have a reasonably close idea of their price. In a particular year, unusual weather or fresh market conditions may cause the final grower price to deviate some from the price expected at the time the frozen quota is established. This shows up in the unexplained residuals of the equation.[1/]

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1/ It might be argued that P_{gpct} in (14) should be replaced by an anticipated price, P'_{gpct} which may differ from the price ultimately received. The anticipated price, although not observable, would be closely correlated with the realized price, P_{gpct}, and the deviation of the current fresh price, P_{gfct}, from the past average fresh price $\bar{P}_{gfct-1}$. Thus, the current fresh market price would appear indirectly in the empirical equation. Initial explorations indicated that this formulation involved major simultaneous estimation problems (including nonlinear forms), plus some intercorrelation problems. In view of these difficulties and the potentially small improvement in the parameter estimates, the formulation involving P_{gfct} explicitly was abandoned.

We would expect the coefficient b_{81} in (14) to be positive and b_{82}, b_{83}, and b_{84} to be negative. The values of $\frac{Q_{pct}}{D_{pct-1}}$ and P_{gpct} are determined by simultaneous solution of Equations (12) and (14). The resulting quantity of frozen pack then enters as a variable in (1) in determining the final acreage adjustment.

Fresh market allocation equation.--The quantity sold fresh (Q_{fc}) is equal to the total production (Q_c) less the quantity allocated to freezing.

$$(15) \quad Q_{fct} = Q_{ct} - kQ_{pct}$$

where k is a factor for converting from frozen product to raw product weight.

Frozen Product Demand and Inventory Allocation

This section deals with demand and supply relationships for the final frozen product. Three types of relationships are involved: (1) a behavioral equation which describes the demand facing freezers, (2) a short-run supply equation (behavioral) which determines the quantity processors desire to allocate to current sales, and (3) an identity which determines the allocation to carryover stocks, given the initial total supply and the allocation to sales.1/

Demand Facing Freezers

The demand facing freezers of Brussels sprouts involves essentially the same variables as the fresh market demand, plus the percent of U.S. homes with refrigerators (R). The latter is used as a proxy variable to indicate, in part, the shift toward consumption of vegetables in frozen

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1/ Alternatively, we could have specified a processor demand equation for carryover stocks. In this case, the carryover stocks would have been determined directly by the behavioral equation, rather than indirectly through an identity. However, the identity which equates ending stocks plus sales with total supply would still be required for an allocation solution. The two formulations lead to identical results.

form. The equation form, with all variables measured in logs as in the fresh demand (which expresses the relationship in percentage terms) is as follows:

$$(16)\quad P_{pct} = a_{10} + a_{11}X_{bpt} + a_{12}X_{bft} + a_{13}X_{vt} + a_{14}F_t + a_{15}R_t + u_{1t}.$$

The price of grade A sprouts in 10-ounce packages is used as a representative price. This is the highest volume product and prices of other packages and styles tend to move closely with it. The variables X_{vt}, F_t, and R_t are exogenous. For reasons discussed previously, per capita fresh sales (X_{bft}) although endogenous in the total model, is regarded as predetermined in (16). Price (P_{pct}) and per capita frozen sales (X_{bpt}) are jointly determined, suggesting that the parameters of (16) should be estimated simultaneously with those of the sales allocation equation to be discussed shortly. In practice, the simultaneous and single equation estimates turned out to be almost identical, for reasons to be explained in the empirical section.

Sales Allocation of Freezers

The quantity of frozen Brussels sprouts sold during a particular year is determined by a complex weighing of current prices, expected future prices, levels of inventories, and costs of holding inventories. The representation of this relationship in mathematical terms involves difficult problems of selecting an appropriate equation form and relating the expected future prices to observable variables. Expectations concerning future (next period) prices seem likely to be based on past average ("normal") prices and might therefore show up mainly as either a constant or a trend factor. Inventory costs are difficult to measure and except for recent large interest rate increases, appear not to have changed greatly from one year to the next. Thus, the influence of this variable might also show up as a constant (or a constant proportion of price). With these considerations, the sales allocation equation might be expressed crudely as follows:

$$(17)\quad D_{pust} = a_{20} + a_{21}P_{pct} + a_{22}(Q_{pust} + S_{ust}) + u_{2t}.$$

Equation (17) expresses the total sales in the United States market as a linear function of the current price and beginning total U.S. stocks plus quantity packed. The joint nature of D_p and P_p suggests that the parameters of (17) might be estimated most appropriately as part of a simultaneous system involving the demand equation facing freezers. Statistical explorations with this crude simultaneous model (including logarithmic variations) gave generally unsatisfactory results, particularly with reference to the significance of the effects of current prices on sales allocations. In view of this problem and the difficulty noted in specifying the structure of the inventory model, we have developed an alternative formulation to predict the sales-inventory allocation.

The basic argument of the alternative approach is that freezer allocations to current sales can be predicted with considerable accuracy on the basis of initial total supplies (beginning stocks plus quantities packed) and the extent to which this supply exceeds previous sales. That is,

$$\text{(18)} \quad D_{pust} = a_{30} + a_{31}(Q_{pust} + S_{ust}) + a_{32}(Q_{pust} + S_{ust} - D_{pust-1}) + u_{3t}.$$

Again, consistent with the formulation of the demand model, all variables refer to total U.S. quantities.

This equation form reflects a balancing of the increased pressure of larger than normal supplies (or short supplies) and the freezer's desire to maintain an orderly flow of marketings. All variables on the right are predetermined, suggesting that a single equation approach may be appropriate for estimating the parameters of (18). We would expect a_{31} to be positive and a_{32} to be negative. Thus, sales increase with increases in available supply, but the proportions of initial supply marketed decreases as the level of supply increases relative to the disappearance of the previous year.

Inventory Allocation of Freezers

The freezer allocation to stocks to be carried into the next production period is given by the identity,

$$(19)\quad S_{ust+1} = Q_{pust} + S_{ust} - D_{pust}.$$

Equations (17) or (18) may be substituted into (19) to obtain a behavioral equation which directly predicts carryover stocks, S_{ust+1}. The latter may be viewed as a freezer demand equation for carryover stocks.

EMPIRICAL ESTIMATES OF SUPPLY AND DEMAND RELATIONSHIPS

Estimates of the parameters of the equation forms described in the previous section were developed from data covering the period 1947 to 1967. "Official" data pertaining to grower prices and acreage are available only to 1949. To make maximum use of the other data series, crude estimates of the 1947 and 1948 values of grower prices and acreage were developed for use in the total analysis.

Farm Production

The parameters of the California acreage adjustment equation were estimated by ordinary least squares (OLS) since all variables affecting acreage are regarded as predetermined.[1/] The acreage and production equations are as follows (values in parentheses are standard errors, R is the correlation coefficient, and d is the Durbin-Watson Statistic).

1/ The quantity to be packed, Q_{pct}, is predetermined with respect to acreage because it is established in late spring without joint reference acreage planted. See the previous discussion of economic structure.

Acreage Adjustment in California

$$\text{(1A)} \quad A_{ct} = A_{ct-1} + 110.15 + \underset{(109.43)}{408.16} (M_{gct-1} - M_{gct-2})$$

$$+ \underset{(13.58)}{28.70} (Q_{pct} - Q_{pct-1}) - \underset{(510.63)}{532.79} (L_t - L_{t-1})$$

where

$$M_{gct} = P_{gct} - C_{gct}. \quad R = .825, \; d = 2.25.^{1/}$$

Total Production in California

$$\text{(2A)} \quad Q_{ct} = B_{ct} \cdot A_{ct}.$$

The signs of the coefficients of (1A) are all consistent with theoretical expectations and the major coefficients (i.e., for M_{gc} and Q_{pc}) are large relative to their standard errors. The estimates thus seem good in a statistical sense, although there remains a considerable amount of variation to be explained stochastically as a result of omitted factors.

Equation (1A) indicates, for example, that a one cent per pound change in the average grower price for all sprouts, measured as a deviation from average cost, has been associated on the average with a change of about 408 planted acres in the same direction. The coefficient of $Q_{pct} - Q_{pct-1}$ in (1A) measures the effect of the "second stage" adjustment in grower plans when the frozen quota becomes known. It indicates that (say) a one million pound change in allocation to freezing is associated with a 28.7 acre modification of planting plans, with other variables constant. With average yields of about 11,500 pounds per acre, production would change by 330,000 pounds, or 281,000 pounds in frozen product terms. The less than full modification (i.e., 281,000 vs. 1,000,000) reflects grower reluctance or inability to alter production plans greatly within a short period. Note that if the frozen pack is equal to the previous year's pack and there is no change in profitability ($M_{gct-1} - M_{gct-2} = 0$), Equation (1A) predicts the acreage in year t to increase by 110 over the previous year, indicating a slight upward trend not fully accounted for by the equation variables. The coefficient

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1/ Hypothesis of independence of error terms not rejected at the 5 percent significance level.

-532.79 suggests a downward adjustment in the level of acreage with the establishment of the market order program.

Farm Level Demand and Raw Product Allocation

Four equations are involved in this component of the model. The parameters of three of these--the California freezer demand for raw product and the grower allocation equations--were estimated simultaneously by two-stage least squares. For convenience of exposition we shall present and discuss the three equations as a group. The fourth equation--the fresh market demand--was estimated singly by ordinary least squares and will be considered separately.

Freezer Raw Product Demand

$$(12A)\quad \frac{Q_{pct}}{D_{pct-1}} = 1.5352 + \underset{(0.0178)}{0.0576}\,(P_{pct-1} - C_{pct-1} - 1.172\,P_{gpct}) - \underset{(0.4169)}{1.8455}\,\frac{S_{ust}}{D_{pust-1}} - \underset{(0.0903)}{0.0350}\,L_t.$$

Frozen Allocation

$$(14A)\quad \frac{Q_{pct}}{D_{pct-1}} = 0.2853 + \underset{(0.0484)}{0.2551}\,P_{gpct} - \underset{(0.0473)}{0.0754}\,\bar{P}_{gfct-1} - \underset{(0.0696)}{0.0787}\,C_{gct} - \underset{(0.1540)}{0.4687}\,L_t$$

where

$$\bar{P}_{gfct} = \frac{1}{2}\,(P_{gfct-1} + P_{gfct-2}).$$

Fresh Allocation

$$(15A)\quad Q_{fct} = B_{ct}A_{ct} - 1.172\,Q_{pct}.$$

The signs of the equation coefficients again are all consistent with theoretical expectations and most are large relative to their standard errors (in parentheses), which refer to the second stage of the TSLS.

Equation (12A) indicates that the demand of freezers for raw product increases with the sales and f.o.b. price of the previous year and decreases with increases in cost, grower price, and levels of stocks relative to past period sales. Raw product demand may have shifted downward slightly but not significantly with the establishment of the Brussels Sprouts Marketing Program (when $L_t = 1$). To give more specific interpretation, a one cent increase in the past period f.o.b. price or decrease in unit cost has been associated with a 5.76 percent increase in demand for pack relative to the previous year's sales. The effect of a change in grower price is determined by first multiplying the coefficient .0576 by the frozen to raw product conversion factor, 1.172, giving a value of .0675. Thus, a one cent increase in grower price has decreased the quantity demanded by freezers by 6.75 percent of the previous year's sales.

In the earlier discussion of structural relations it was noted that a value of -1.0 for the coefficient of the stock variable $(\frac{S_{ust}}{D_{pust-1}})$ could be regarded as indicating a neutral reaction on the part of processors. The high value (-1.84) obtained in (12A) suggests a tendency on the part of freezers to give more weight to inventory carryover levels than would be required merely to adjust inventories to average levels. This may lead to greater fluctuations in stock and/or production than might occur with a more neutral reaction.

Equation (14A) is interpreted similarly to (12A). It measures the quantities of Brussels sprouts which growers desire to allocate to freezing for varying levels of current raw product price for freezing, the average fresh market price for the past two years, and the average cost of production. Note that the dummy shift variable L_t is much more significant in the grower equation than in the processor demand equation. This seems highly consistent with our original hypothesis concerning the effects of the Brussels Sprouts Marketing Program. It suggests that beginning in

1958, growers became more restrictive in the quantities which they desired to allocate to freezing--or put another way, their aspiration price increased. Processor attitudes, on the other hand, appear to have been only mildly altered, if at all, by this program.

Each of the equations, taken alone, may be used to make conditional predictions. For example, if we specify the grower price for frozen sprouts along with the values of the predetermined variables, we may predict the quantity processors wish to freeze (12A) and the quantity growers desire to allocate to freezing (14A). These, of course, will not necessarily be identical quantities except for a particular price. To make unconditional forecasts--i.e., to predict expected quantities--we solve the two equations simultaneously for the grower price which will equate the quantity growers desire to supply for freezing with the quantities freezers wish to buy. The solution depends on the values of the exogenous or lagged endogenous variables in the equations, which are known at the beginning of each crop year. Given this solution, quantities allocated to the fresh market then are determined as in Equation (15A).

Fresh Market Demand

Exploratory application of least squares regression to the fresh market demand equation (13) quickly revealed a serious problem--the tendency of per capita food expenditures, F, (or income, if used) and per capita disappearance of frozen Brussels sprouts, X_{bp}, to move together historically in such a way as to make determination of their separate influence very difficult. One means of coping with such difficulties is to introduce additional constraints into the model, either from other empirical knowledge or from logical inference. We have followed the latter procedure.

We argued that, with all other variables constant, a given percentage change in F ought to produce about the same percentage change in the price of Brussels sprouts. That is, a one percent increase in undeflated expenditures on food, with quantities constant, would tend to increase price by one percent if the allocation of consumer expenditures did not change appreciably. In the logarithmic equation the coefficient for F simply becomes

1.0. Consumer allocations of expenditures may change, of course, with changes in total income and food expenditures. However, unless there was a dramatic change, the coefficient for F would be somewhere in the neighborhood of 1.0.

With this restriction, the parameter estimates of (13) were as follows:

$$\text{(13A)} \quad \log P_{gfct} = 5.6766 - \underset{(0.1317)}{0.5830} \log X_{bpt} - \underset{(0.1954)}{0.6887} \log X_{bft}$$

$$- \underset{(1.8737)}{3.5835} \log X_{vt} + 1.0000 \log F_t$$

$$R = 0.75, \ d = 1.62.$$ [1/]

The value of R refers to the multiple correlation coefficient with $\log P_{gfct} - \log F_t$ as the dependent variable. Again, the signs of the coefficients are all consistent with theoretical expectations and they are all large relative to their standard errors.

The coefficients of (13A), often referred to as <u>price flexibilities</u>, show the effect on the fresh Brussels sprouts price of a one percent change in associated quantity with all other variables, including random disturbances, constant. For example, (13A) suggests that, if we hold other things constant, a one percent increase in per capita disappearance of fresh Brussels sprouts has been associated with about a 0.69 percent decrease in fresh price. A similar increase in marketings of frozen sprouts reduced the fresh price by about 0.58 percent. A one percent increase in total per capita vegetable consumption reduced the fresh Brussels sprouts price by about 3.6 percent. Note that although the coefficient for total vegetables is much larger than the Brussels sprouts coefficient (3.58 compared to 0.69), a rather large absolute quantity change in total vegetables is required for the same price effect as a small change in quantity of Brussels sprouts. This is due to the much larger magnitude of total vegetable consumption (e.g., 146 pounds per person compared to 0.23 for Brussels sprouts).

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1/ Value of d lies in the indeterminant range for a 5 percent level of significance.

Frozen Product Demand and Inventory Allocation

This component of the model involves two behavioral equations--the demand facing freezers and the sales allocation of freezers--plus an identity to obtain the associated allocation to carryover stocks. Two alternative formulations of the sales allocation equation were considered: (1) a model involving current price, as well as sales, thus requiring joint estimation of the demand and sales allocation equations, (16) and (17); and (2) a model which predicts sales as a function of quantity packed plus initial stocks and the quantity sold the previous year. In this case the demand and sales allocation equations, (16) and (18), are estimated separately by ordinary least squares. We shall present both sets of estimates for each behavioral equation.

Demand Facing Freezers

As in the case of the demand for fresh sprouts, estimation of the demand facing California freezers is complicated by high intercorrelation among some of the explanatory variables. Two restrictions were imposed to cope with this problem. First, we combined R and F into a single variable $Y = R \cdot F$. This simply assumes that only those families with refrigerators are an effective part of the market for frozen vegetables. It ignores institutional consumption, but growth in the percentage of refrigerator ownership appeared highly correlated with the early growth of the frozen vegetable market. Today more than 99 percent of all U.S. homes have refrigerators--see Appendix Table A-20. Second, we again constrained the coefficient of the per capita food expenditure variable in the manner indicated for the fresh demand--i.e., the coefficient of Y is assigned a value of 1.0 in the log form of Equation (16).

With these restrictions, the parameter estimates of Equation (16) were as follows:

Ordinary least squares

$$\text{(16A)}\quad \log P_{pct} = 5.8161 - \underset{(0.0780)}{0.6322} \log X_{bpt} - \underset{(0.1157)}{0.1528} \log X_{bft}$$

$$- \underset{(1.1095)}{3.2167} \log X_{vt} + 1.0000 \log Y_t$$

$R = 0.94$, $d = 1.70$.[1/]

Two-stage least squares

$$\text{(16B)}\quad \log P_{pct} = 5.8975 - \underset{(0.0775)}{0.6747} \log X_{bpt} - \underset{(0.1130)}{0.2020} \log X_{bft}$$

$$- \underset{(1.0508)}{3.2898} \log X_{vt} + 1.0000 \log Y_t.$$

The value of R is the multiple correlation with $\log P_{pc} - \log Y$ as the dependent variable. The standard errors for the TSLS estimate refer to values obtained with the second-stage regression. Although the usual significance tests are not strictly appropriate in the latter case, the values give some idea of the strength of the estimates. In these terms, the TSLS estimates appear slightly superior to the OLS, but the difference is very small and the values of regression coefficients are nearly the same for each method of estimation. In both cases the signs of all coefficients are consistent with theoretical expectations and are generally substantially larger than their standard errors.

The coefficients of these equations are interpreted in the manner described for the fresh market demand equation. That is, they show the percentage change in price resulting from a one percent change in the associated quantity with all other variables (including random disturbances) constant. The coefficients are of the same general order as those in the comparable fresh demand (Equation 13A) except that the quantity of fresh sprouts (X_{bf}) affects the frozen price less than the quantity of frozen sprouts (X_{bp}) affects the fresh price. This seems plausible with annual data since frozen sprouts are always available to compete with fresh, whereas fresh sprouts compete with frozen during only a part of the year.

1/ Hypothesis of independence of error terms not rejected at the 5 percent significance level.

Sales Allocation of Freezers

Simultaneous model (two-stage least squares)

$$(17A)\quad \log D_{pust} = -0.1572 + \underset{(0.0520)}{0.9905} \log (Q_{pust} + S_{ust})$$

$$+ \underset{(0.3457)}{0.0417} \log P_{pct}.$$

Single equation model

$$(18A)\quad D_{pust} = 2.4439 + \underset{(0.0568)}{0.7832} (Q_{pust} + S_{ust})$$

$$- \underset{(0.1426)}{0.2399} (Q_{pust} + S_{ust} - D_{pust-1})$$

$$R = .97,\ d = 2.42.$$

Equation (18) was also fitted in terms of logarithms with very similar results in terms of significance measures. Comparing (17A) and (18A), the coefficient of price in (17A), while showing the correct sign, is of doubtful significance. The single equation model (18A) appears to provide a slightly stronger basis for sales prediction, particularly if we allow in the statistical interpretation for the loss of an observation due to the lagged variable. It "explains" more than 93 percent of the variance in total disappearance during the 20-year period included. It indicates that disappearance changes at the rate of about 78 percent of total beginning supplies of frozen sprouts, with a downward adjustment as the level of supplies increases relative to sales of the previous year.[1/] Use of this equation in the total model suggests that we should also use Equation (16A) based on OLS to represent the demand facing freezers.

- -

1/ Equation (18A) could be expressed more directly as $D_{pust} = 2.4439 + .5433 (Q_{pust} + S_{ust}) + .2399 D_{pust-1}$.

Inventory Allocation of Freezers

The allocation to carryover stocks, S_{ust+1}, may be obtained by substituting either (17A) or (18A) into Equation (19). Substituting (18A) gives:

$$\text{(19A)} \quad S_{ust+1} = 2.4439 + 0.2168\ (Q_{pust} + S_{ust}) + 0.2399\ (Q_{pust} + S_{ust} - D_{pust-1}).$$

SIMULATION OF THE BRUSSELS SPROUTS ECONOMY

The estimates of demand and supply relationships developed in the previous sections provide the materials needed to formulate a model which simulates the process of production adjustment and price change in the Brussels sprouts economy. The validity of the model is tested by comparing the output generated following an initial set of inputs, with actual prices and production during the period 1950-1967. On concluding that the model has predicted with a reasonable degree of success, we then use it to inquire, conditionally, into the potential effects of alternative marketing policies, technological developments, and trends or changes in product demand.

Summary of the Model

Mathematical models of economic systems consist of components, variables, and functional relationships. The components of the model of the Brussels sprouts economy are the producers, the freezers, and the buyers of frozen and fresh market sprouts. The variables of the model relate to the components and are classed as exogenous or endogenous variables. Exogenous variables are variables which affect the system but whose values are assumed to be determined or given independently of the system being modeled. Endogenous variables are variables whose values are generated within the model.

The functional relationships, which describe the interaction of the variables and components of the system, are of two types--behavioral relationships and identities. Both are used to generate the behavior of the system. The supply and demand equations estimated in the previous section are behavioral relationships. Identities are either definitions or tautological statements about the components of the model. For example, the statement that the U.S. quantity of Brussels sprouts frozen is equal to the quantity frozen in California plus the quantity frozen in other regions, is an identity.

Variables

The variables of the system are described and identified in the section dealing with the structure of the Brussels sprouts economy (see Table 8). They are listed below according to their classification in the simulation model.

Endogenous variables: A_c, Q_c, Q_{pc}, Q_{fc}, P_{gpc}, P_{gfc}, P_{gc}, Q_{pus}, Q_{fus}, S_{sus}, D_{pc}, D_{po}, D_{pus}, P_{pc}, X_{bp}, X_{bf}.

Exogenous variables: C_{gc}, B_c, Q_o, Q_{po}, Q_{fo}, L, C_{pc}, N, X_v, F, Y, u, v.

Behavioral Relationships

The model of the Brussels sprouts economy involves six behavioral relationships derived from the structural equations estimated in the previous section. For prediction and simulation purposes, the simultaneously determined equations (12A) and (14A) are not used directly in their original form. Rather, they are solved for each of the endogenous variables expressed as functions of the remaining exogenous or lagged endogenous variables. The equations obtained by solving these simultaneous equations are referred to as reduced forms. They are designated below as Equations (20) and (21).

Note that the value of the frozen pack (Q_{pct}) predicted by the reduced form equation then enters as a variable in the equation which predicts acreage adjustments.

1. <u>California frozen pack.</u>

$$(20)\quad Q_{pct} = D_{pct-1}\,[1.2737 + 0.0455\,(P_{pct-1} - C_{pct-1}) - 1.4594\,\frac{S_{ust}}{D_{pust-1}} - \frac{0.0158}{2}\,(P_{gfct-1} + P_{gfct-2}) - 0.0165\,C_{gct} - 0.1257\,L_t].$$

2. <u>California acreage adjustment.</u>

$$(1A)\quad A_{ct} = A_{ct-1} + 110.15 + 408.16\,(P_{gct-1} - P_{gct-2}) - 408.16\,(C_{gct-1} - C_{gct-2}) + 28.70\,(Q_{pct} - Q_{pct-1}) - 532.79\,(L_t - L_{t-1}).$$

3. <u>California grower price for freezing.</u>

$$(21)\quad P_{gpct} = 3.8744 + 0.1785\,(P_{pct-1} - C_{pct-1}) - 5.7207\,\frac{S_{ust}}{D_{pust-1}} + \frac{0.2337}{2}\,(P_{gfct-1} + P_{gfct-2}) + 0.2440\,C_{gct} + 1.3444\,L_t.$$

4. <u>California grower price for fresh market.</u>

$$(14A)\quad \log P_{gfct} = 5.6766 - 0.5830\,\log X_{vpt} - 0.6887\,\log X_{bft} - 3.5835\,\log X_{vt} + 1.0000\,\log F_t.$$

5. U.S. freezer sales allocation.

(18A) $D_{pust} = 2.4439 + 0.7832\ (Q_{pust} + S_{ust}) - 0.2399\ (Q_{pust} + S_{ust} - D_{pust-1}).$

6. California freezer f.o.b. price.

(16A) $\log P_{pct} = 5.8161 - 0.6322 \log X_{bpt} - 0.1528 \log X_{bft} - 3.2167 \log X_{vt} + 1.0000 \log Y_t.$

7. Other region supply and demand relationships.

(a) Q_{fo} regarded as exogenous (values taken as given or projected) throughout.

(b) Q_{po} regarded as exogenous (values taken as given or projected).

(c) Demand facing other region freezers assumed to be same as for California except for level of price. California price used as a proxy for other region price.

(d) Fresh market demand treated as in (c) above.

8. Imports and exports.

Not included because of a lack of essential data. The potential impact of changes in import levels is explored to some extent in the simulation experiments.

Identities

1. U.S. frozen stocks.

$$S_{ust+1} = Q_{pust} + S_{ust} - D_{pust}.$$

2. California total production.

$$Q_{ct} = B_{ct}\ A_{ct}.$$

3. California fresh market allocation.

$$Q_{fct} = Q_{ct} - 1.172\ Q_{pct}.$$

4. U.S. frozen pack.

$$Q_{pust} = Q_{pct} + Q_{pot}.$$

5. U.S. fresh market sales

$$Q_{fust} = Q_{fct} + Q_{pot}.$$

6. U.S. frozen per capita sales.

$$X_{bpt} = \frac{D_{pust}}{N_t}$$

7. U.S. fresh per capita sales.

$$X_{bft} = \frac{Q_{fust}}{N_t}$$

8. California share of U.S. frozen sales.

$$D_{pct} = \frac{Q_{pct}}{Q_{pust}} \cdot D_{pust}$$

9. Other region share of U.S. frozen sales.

$$D_{pot} = \frac{Q_{pot}}{Q_{pust}} \cdot D_{pust}$$

10. California average grower price.

$$P_{gct} = \left(\frac{1.172\ Q_{pct}}{Q_{ct}}\right) P_{gpct} + \left(\frac{Q_{fct}}{Q_{ct}}\right) P_{gfct}$$

Verification of the Model

Before proceeding to use the model for experimental purposes we must determine whether, in fact, it will generate meaningful values of the endogenous variables involved. Two kinds of tests are applied. The first testing procedure is to start with an initial set of values and then observe the values of prices, acreage, and production generated by the model for a series of past periods. These computed values are compared with actual values to see how well the model performs.

The second test is to examine the output generated by the model for future periods with respect to its *a priori* plausibility. For example, if the fresh and frozen market grower prices tended to diverge widely or if profit margins became abnormally high or low and remained there, this would suggest a need for reexamination or adjustment of the model. This aspect of the testing procedure is considered in the process of performing simulation experiments with the model.

In generating the output of the model the disturbance terms (the u_i and v_i) are set equal to zero. This greatly reduces the computations involved. The predictions of the model are in terms of expected values--i.e., trend or average levels of the endogenous variables. This type of prediction is most appropriate for making long-term projections of the potential effects of alternative marketing policies or changes in the environmental factors influencing the Brussels sprouts economy.

Alternatively, the stochastic elements could be introduced on the basis of the estimated variances of the behavioral equations and an assumed normal distribution of the unexplained disturbances. This procedure would have the advantage of testing the sensitivity of the sequence of model predictions to the random disturbances and could provide a range of values for future projections for which probabilities might be determined. The difficulty with this approach is that it requires many repeated computer runs to approximate the stochastic pattern of model predictions. Computer costs may be 30 to 50 times greater than with the deterministic model in which the disturbances are specified as zero. With several simulation experiments

to consider this can become a costly procedure. Consequently, we have elected to generate only the expected values of the model output.

The sequence of computations required to generate the output of the simulation model is illustrated in Figure 16. The process begins by reading into the computer all values of variables that are exogenous or treated as exogenous to the system, plus the initial first period values of the endogenous variables. Beginning inventory levels are computed for the second year as determined by pack, sales, and beginning inventories of the previous period. This, along with predetermined values of other variables, provides the means of computing California grower prices for freezing and quantity frozen. The quantity to be frozen and past prices and costs are used to compute California acreage. California total production and fresh market sales then are determined by Identities 2 and 3.

Since quantities of sprouts produced in other regions are treated exogenously, total U.S. frozen pack and fresh market sales are computed by adding these given values to the computed values for California. U.S. frozen sales are determined by the U.S. pack, beginning stocks, and previous period sales (Equation 18A). The frozen and fresh market sales are then expressed on a per capita basis and these values used to compute f.o.b. freezer prices and grower-shipper prices for fresh sprouts. Regional sales values (the D_{pc} and D_{po}) are then calculated to be utilized in calculating California acreage, grower prices, and frozen pack the next year. Time is then advanced one year and the process is repeated.

A consideration in testing and using the model is the selection of the initial values of the endogenous variables needed to start it operating. For example, starting with the actual values for 1947 generates a different sequence of model predictions than starting with 1948 values. If we happen to select a starting year with highly unusual values of some of the endogenous variables, the model predictions may deviate more from actual values, at least during the early periods, than they would if the initial values had been closer to their expected magnitudes. Test runs were made with initial inputs for several alternative years. All produced outputs that moved with the general pattern of actual values. The closest approximation was obtained by using average values for the period 1947-1949 and 1948-1950 as initial inputs.

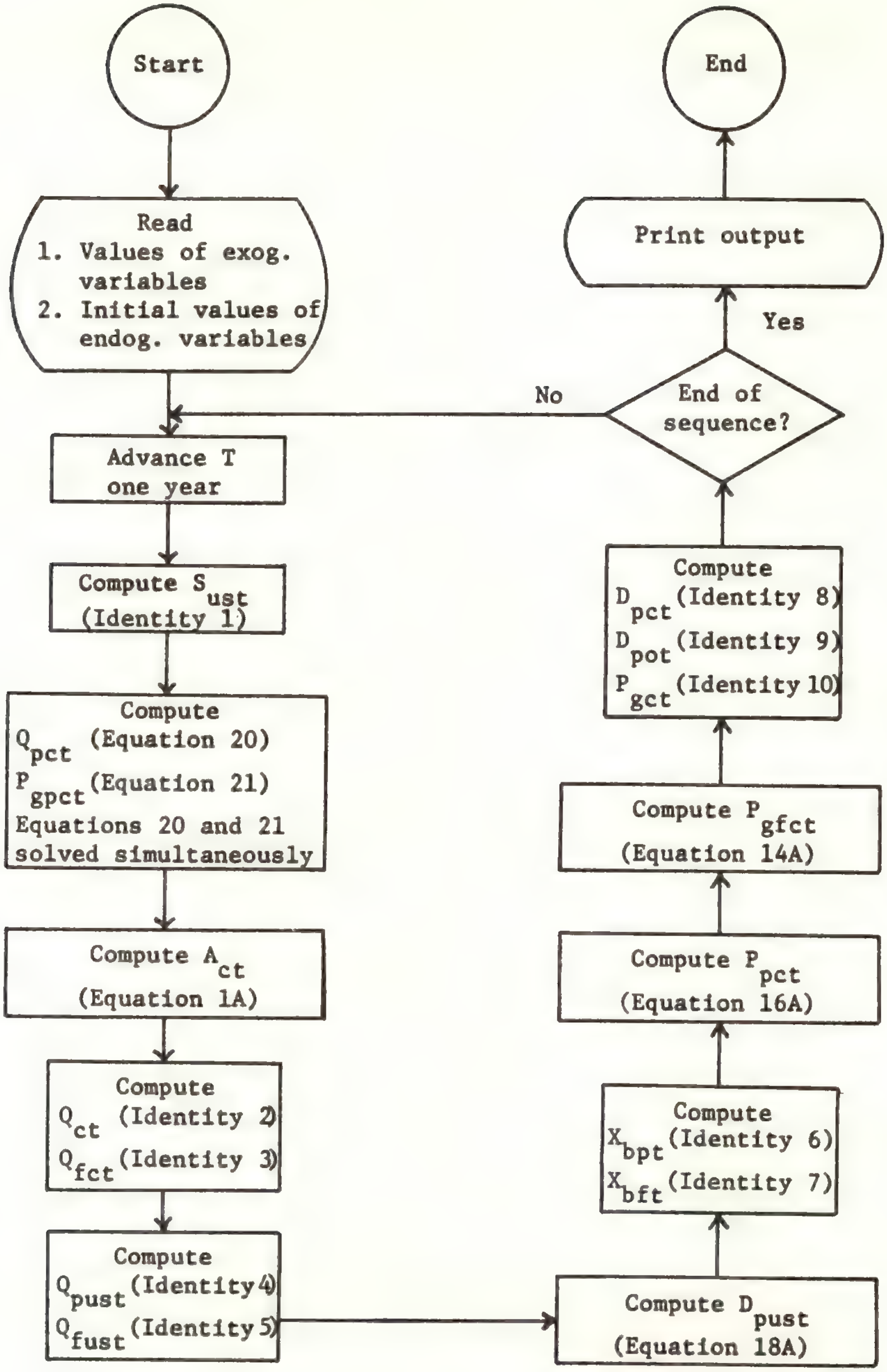

FIGURE 16

Computer Flow Chart for the Brussels Sprouts Simulation Model

Model predictions of seven key variables, generated using average 1947-1949, 1948-1950 average values as initial inputs, are compared with actual values in Figures 17 and 18. Comparisons for the other nine endogenous variables of the system are similar. In general, the predicted values show the same overall trend pattern as the actual values. The predictions show less year-to-year variation since the disturbance terms are set at zero in the model. Since the model uses past predicted values of endogenous variables to make further predictions and suppresses the unexplained year-to-year disturbances, its output may at times cycle above and below the actual values. This is to be expected. The important thing is that the predictions do not drift away--the directions and levels of change are similar.[1/]

It appears that the model is able to generate meaningful results and we shall now proceed to use it to perform experiments which may provide insight into the potential effects of alternative marketing policies, technological developments, and changes in demand and competing production.

Simulation Experiments

Many questions may be asked of a model such as we have developed and answers obtained which may be useful in making future plans and shaping marketing policies. We have selected several types that seem particularly pertinent for these purposes. They are grouped into four kinds of experiments pertaining to (1) effects of changes in demand, (2) effect of changes in competing supplies, (3) effects of changes in technology, and (4) effects of changes in marketing policy.

The manner of asking questions of the model bears importantly on the answers obtained. For example, if we wish to assess the impact of a reduction in costs we must specify not only how much, but at what rate the cost change will occur. Generally, our projections involve gradual, rather than

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1/ Note that the model may also be used to make single-year predictions (one period change) by feeding in the actual, rather than predicted previous period values of endogenous variables. These predictions do not cycle and may be much closer during periods of wide fluctuations. However, they do not test the ability of the model to generate meaningful cumulative series of projections over future periods.

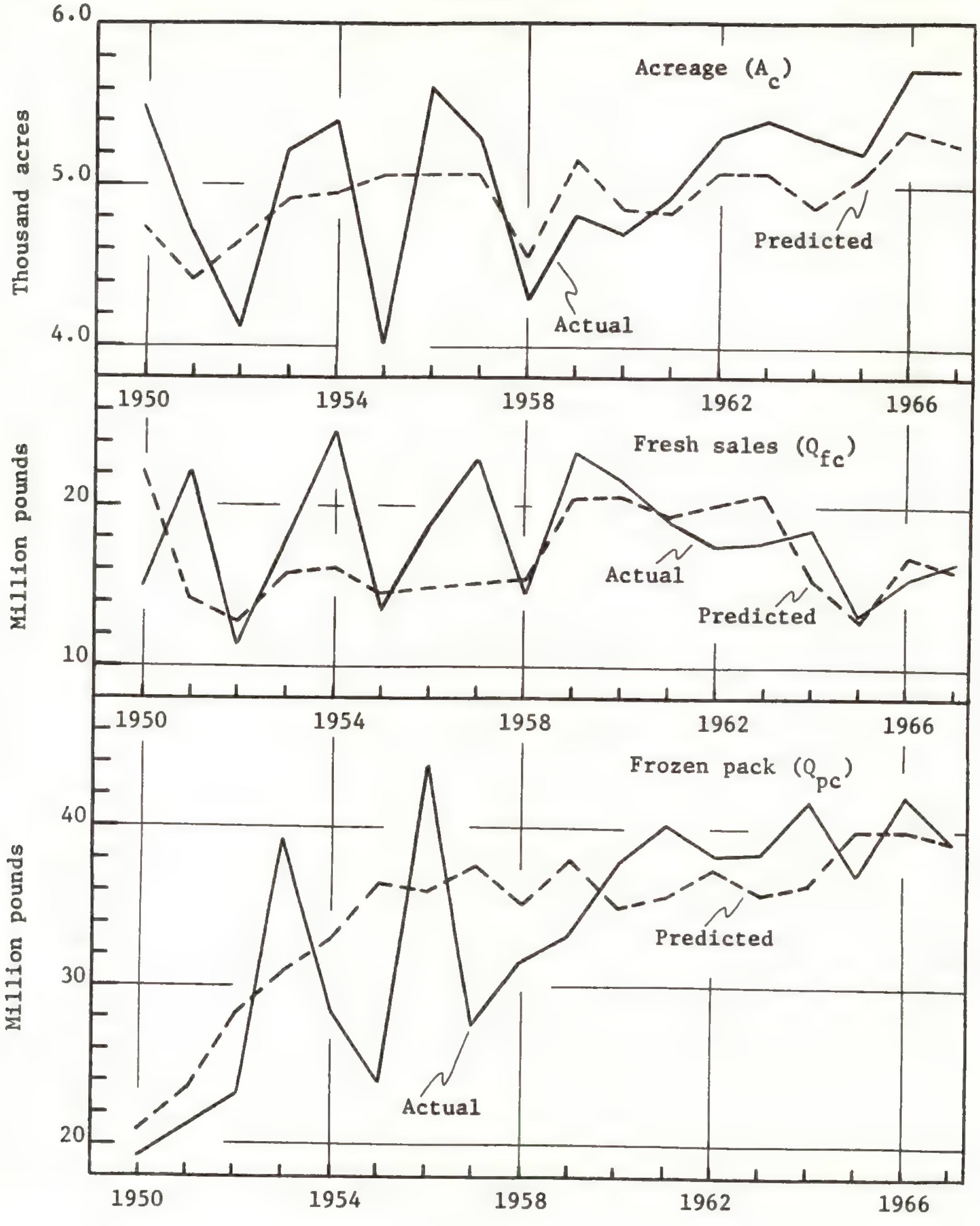

FIGURE 17

Simulation Model Predictions Compared with Actual Values of California Acreage, Fresh Market Sales and Frozen Pack, 1950-1967

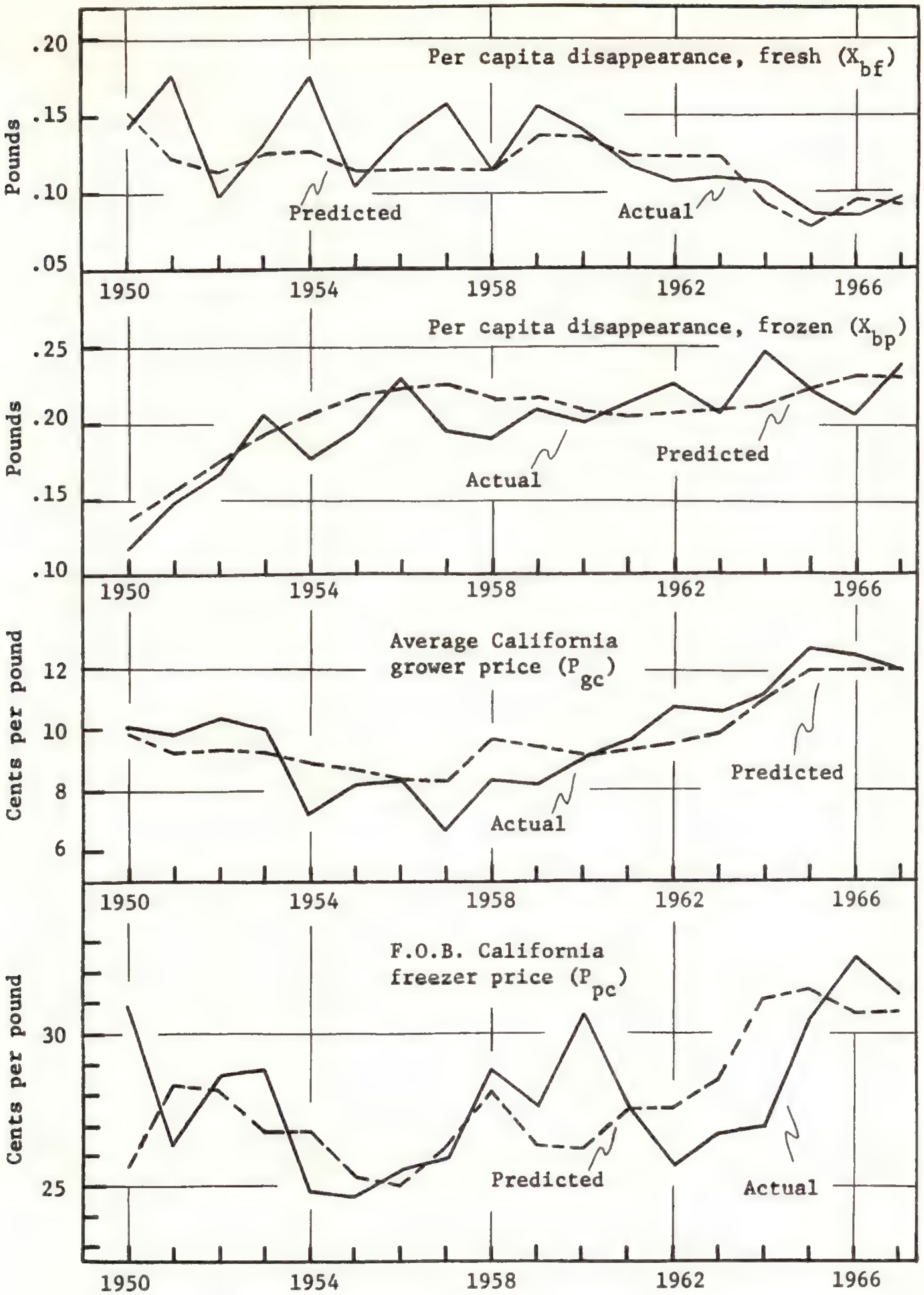

FIGURE 18

Simulation Model Predictions Compared with Actual Values of U.S. Per Capita Disappearance of Fresh and Frozen Brussels Sprouts, Average California Grower Price and F.O.B. California Freezer Price Quotations, 1950-1967

precipitous changes, although the impacts of larger or faster acting shocks or changes could be evaluated readily. To experiment with the model we start it operating with an initial input of actual 1967 and 1968 values of endogenous and exogenous variables. Alternative projections or situations concerning the exogenous variables then are imposed and the model permitted to generate values of the endogenous variables to 1990.

The initial experiments with the model uncovered a serious problem. As some of the exogenous variables were projected beyond the range observed during 1947-1967, the grower prices in fresh and frozen markets tended eventually to diverge and, in some cases, to produce negative (and therefore explosive) quantities in the fresh market. To counter this difficulty, we imposed the following restrictions on the values which grower prices could assume.

(1) $P_{gpc} \geq C_{gc}$. This specifies that the grower price for processing must not fall below the cost of production. While prices might fall below costs in particular years, in the long run quantities would be held to a level that would at least equate price with cost.[1/]

(2) $P_{gfc} \geq C_{gc} + 1.0$. By a similar argument this specifies that the fresh market price must be at least as great as the cost of production plus one cent. The added cent is to allow for added packaging cost involved in the fresh market.

(3) $P_{gfc} \leq P_{gpc} + 2.0$. This restriction prevents the fresh market price from exceeding the grower frozen market price by more than two cents. This is in line with observed average relationships. Persistent differences greater than this amount could be expected to result in some adjustment of allocations between the two markets.[2/]

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1/ We also experimented with restrictions which would permit prices to drop below costs for no more than two successive periods. If this happened, production levels were adjusted in the next period so as to bring prices back in line with costs. The overall trends in projections were much the same as obtained without this embellishment.

2/ Another variation specified that freezer and grower prices could not differ by more than three cents, rather than two. This change had little effect on the values of the major variables generated by the model.

Violations of these restrictions are viewed as occurring because of a failure of the supply component of the model to adjust fully or quickly enough to changing market conditions. Whenever one of the restrictions is violated, quantities allocated to the freezing and fresh markets and California acreage are recomputed so as to give prices that meet the imposed restrictions. With these reasonable constraints, the model projections remain within proper bounds and enable us to focus on the long-run trends suggested by the various experiments.

The Base Model

Because of the many combinations of changes in exogenous variables that might be considered we shall designate a particular combination of projections of these variables as the "base model." The simulation experiments compare the values of endogenous variables, such as acreage, generated by the base model with values obtained by changing the projection of a single exogenous variable such as production cost. The following projections of the exogenous variables define the base model.

1. N (Population). U.S. Bureau of the Census Projection Series C from *Population Estimates*, No. 388, March 1968. (Two-year averages used to convert to approximate crop year basis--see Table 9.)

2. F (Index of per capita food expenditures). Based on 1958-1967 average rate of increase. $F_t = F_{t-1} + 3.20$.

3. Y (Index of food expenditures multiplied by proportion of homes with refrigerators (R)). R assumed constant at .996. This gives $Y_t = Y_{t-1} + 3.19$.

4. X_v (U.S. per capita vegetable consumption). Projected by 1958-1967 least squares trend. $X_{vt} = X_{vt-1} + 0.496$ where $X_{v1967} = 147.58$.

TABLE 9

Base Model Projections of Exogenous Variables[a/]

Crop year	N	F	C_{pc}	C_{gc}	Q_{po}	X_v
1968	202.5	128.5	15.66	11.22	7.263	148.1
1969	204.9	131.7	15.81	11.44	7.992	148.6
1970	207.4	134.9	15.97	11.67	8.721	149.1
1971	209.8	138.1	16.13	11.91	9.450	149.6
1972	212.4	141.3	16.29	12.15	10.179	150.1
1973	215.1	144.5	16.45	12.39	10.911	150.6
1974	217.9	147.7	16.62	12.64	11.637	151.1
1975	220.8	150.9	16.78	12.89	12.366	151.5
1976	223.9	154.1	16.95	13.15	13.095	152.0
1977	227.0	157.3	17.12	13.41	13.824	152.5
1978	230.2	160.5	17.29	13.68	14.553	153.0
1979	233.5	163.7	17.45	13.95	15.282	153.5
1980	236.9	166.9	17.64	14.23	16.011	154.0
1981	240.4	170.1	17.82	14.51	16.740	154.5
1982	243.9	173.3	18.00	14.81	17.469	155.0
1983	247.5	176.5	18.18	15.10	18.198	155.5
1984	251.1	179.7	18.36	15.40	18.927	156.0
1985	254.7	182.9	18.54	15.71	19.656	156.5
1986	258.3	186.1	18.73	16.03	20.385	157.0
1987	261.8	189.3	18.91	16.34	21.114	157.5
1988	265.4	192.5	19.10	16.67	21.843	158.0
1989	269.0	195.7	19.29	17.01	22.572	158.5
1990	272.6	198.9	19.49	17.35	23.301	159.0

a/ Other exogenous variables held constant at the following levels: B_c = .012 (million pounds per acre), L_t = 1.0, Q_{fo} = 2.34. Y is almost identical with F (Y = .996F).

5. C_{pc} (Cost of processing). Projected to increase at the rate of one percent per year. This is roughly the average rate of increase in the Wholesale Price Index during the past 10 years. $C_{pct} = 1.01\ C_{pct-1}$.

6. C_{gc} (Grower cost). Projected to increase at the rate of two percent per year--roughly the average rate of increase in the Index of Prices Paid by Farmers, 1958-1957. $C_{gct} = 1.02\ C_{gct-1}$.

7. B_c (Average California yields. Held at the 1964-1968 average of 11,600 pounds per acre.

8. L_t (Shift variable associated with the Brussels Sprouts Marketing Program). Held at 1.0.

9. Q_{fo} (Fresh market production in regions other than California). Held at 1963-1967 average level of 2.34 million pounds.

10. Q_{po} (Frozen pack in regions other than California). Projected at 1958-1967 average growth rate. $Q_{pot} = Q_{pot-1} + 0.729$.

In addition to the above, the acreage trend value of 110.15 obtained in the equation fitted to 1947-1967 data (Equation 1A) has been deleted for projection purposes. There seems little reason to assume that such a yearly increase will continue without reference to price or cost conditions.

Base model values of exogenous variables not specified to be constant are summarized in Table 9. The projections tend to reflect current trends in most exogenous variables. However, the specific levels of projections are less important than the comparative values generated by alternative projection models.

Projections of endogenous variables generated by the base model are represented by the heavy solid lines in Figure 19 (A, B, C, D) and are repeated again in Figures 20 (A, B, C, D), 21 (A, B, C, D), and 22 (A, B, C, D). The values plotted for 1968 are actual values. Values plotted for all remaining years, including 1969, are predictions of the model for the

conditions specified. The specific values of the base model projections for 1970, 1980, and 1990 are also given in a summary table (Table 10) which appears at the end of this section of the report. The table also shows the deviations from base model projections for each of the several simulation experiments.

The base model suggests that average levels of California acreage (A_c) may increase slightly until the early 1970's, then remain fairly stable until about 1980 and then decline gradually during the next decade. If our yield projection had been slightly lower, as might occur with once-over machine harvest, the level of acreage would be slightly higher, but the general trend would be about the same.

Base model projections of California production suggest a slight decrease in fresh market production (Q_{fc}) and some increase in frozen production (Q_{pc}) during the 1970's. These trends are reversed in the 1980's. Total California production (Q_c in Figure 19-C) shows the same pattern as acreage. California's share of the fresh market remains high and fairly stable while the share of frozen pack declines from 84 to 63 percent (Figure 19-C).

Figure 19-B shows the base model projections of grower and processor prices moving generally upward. In both cases, but particularly for growers, the price (P_{gc}) barely manages to keep ahead of unit cost. This, of course, is to be expected in the long run under conditions of strong competition and relatively easy entry into the industry.

United States per capita disappearance of fresh market sprouts (X_{bf}) declines gradually until about 1980 and then levels off. Per capita disappearance of frozen sprouts (X_{bp}) increases until about 1975 and then moves downward for the remainder of the period. Note, however, that total United States production of frozen sprouts (Q_{pus} in Figure 19-D) continues to increase, but at a decreasing rate.

Effects of Changes in Demand

The first experiment is to see how acreage, production, prices, and market shares are affected by changes in demand. Two types of demand changes were investigated. First, starting in 1970, we allowed the competing products

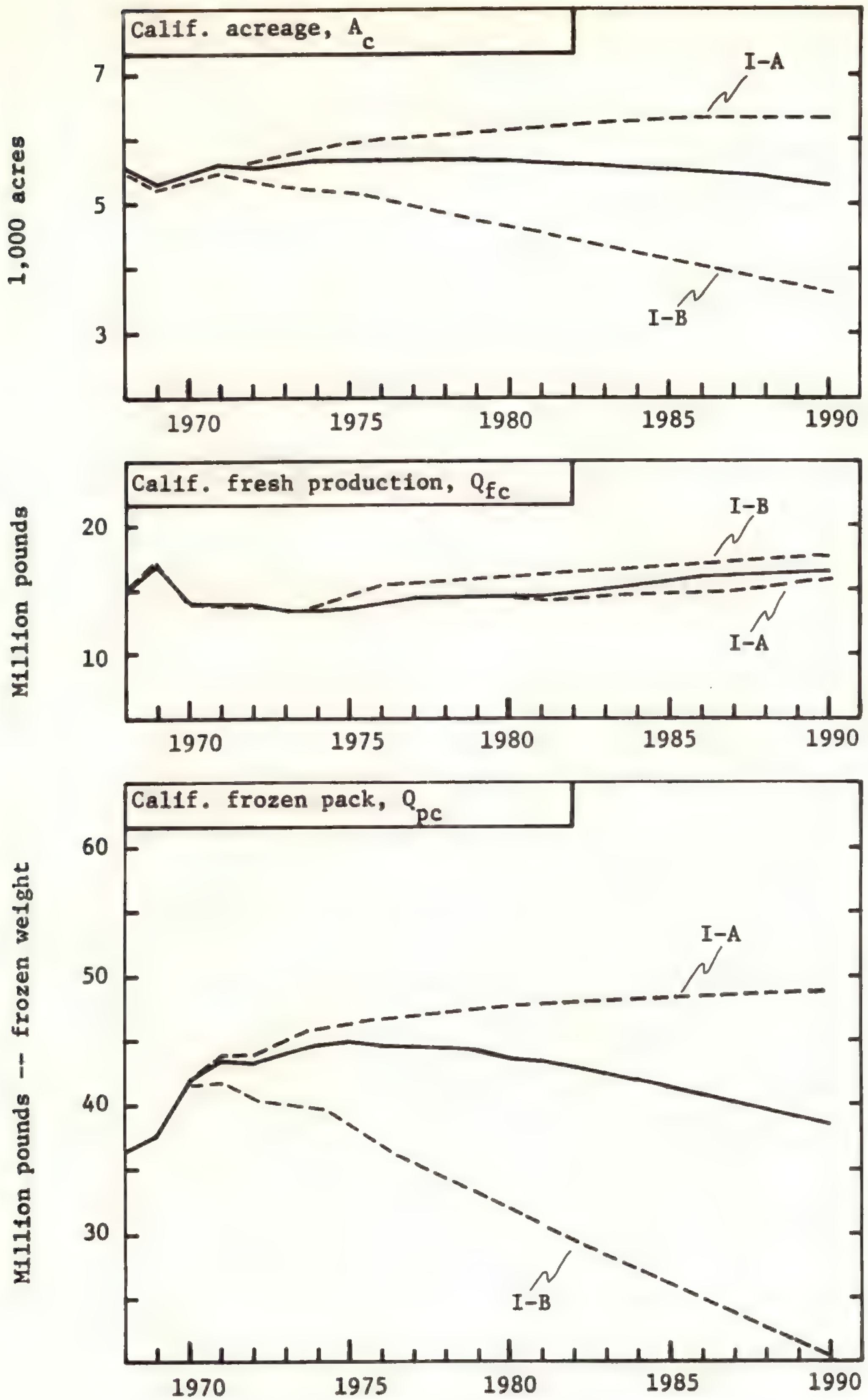

FIGURE 19-A

Simulation Experiment I. Projections of California Acreage, Fresh Market Production, and Frozen Pack

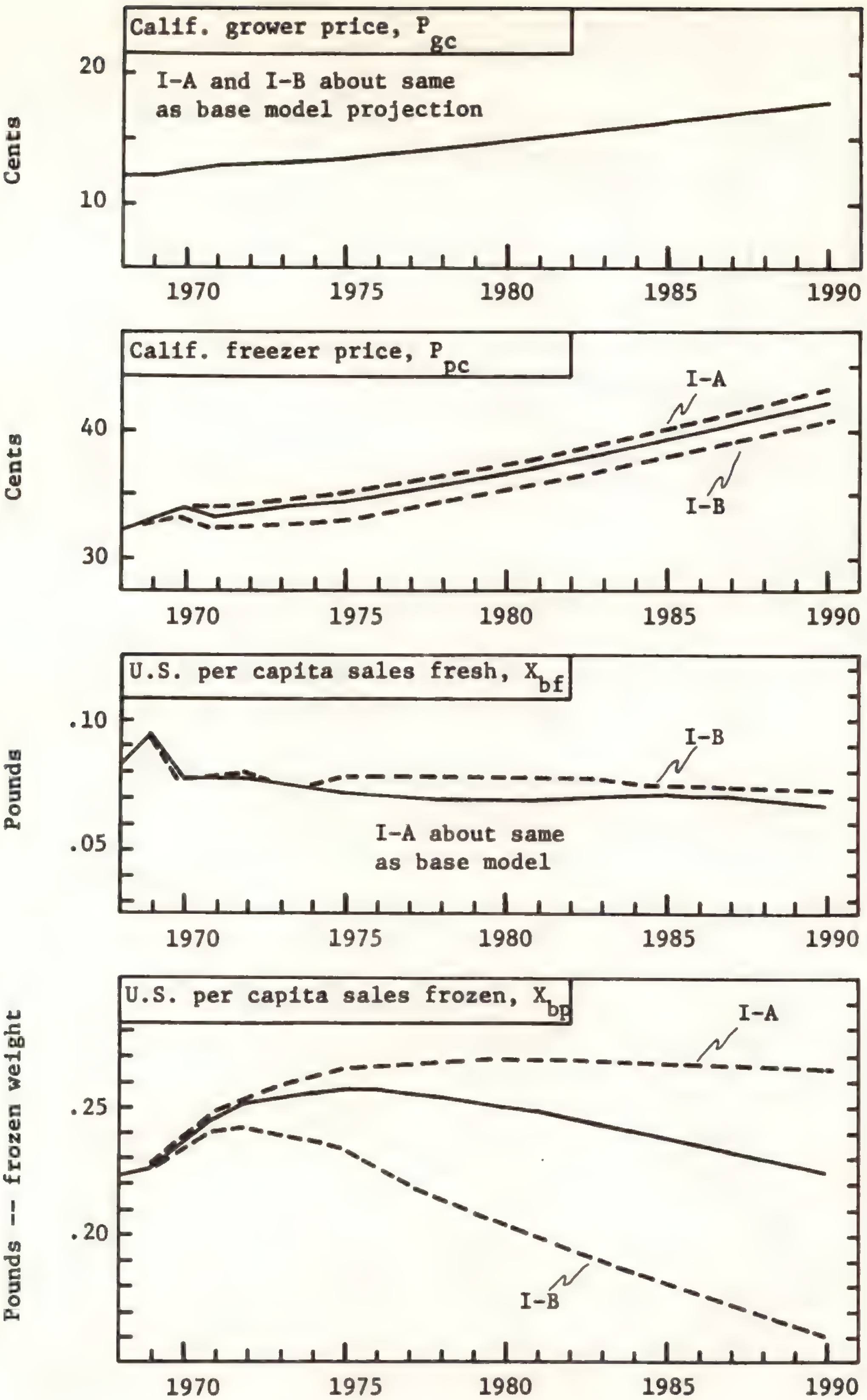

FIGURE 19-B

Simulation Experiment I. Projections of Average California Grower Price, F.O.B. Freezer Price, and Per Capita Disappearance of Fresh and Frozen Brussels Sprouts

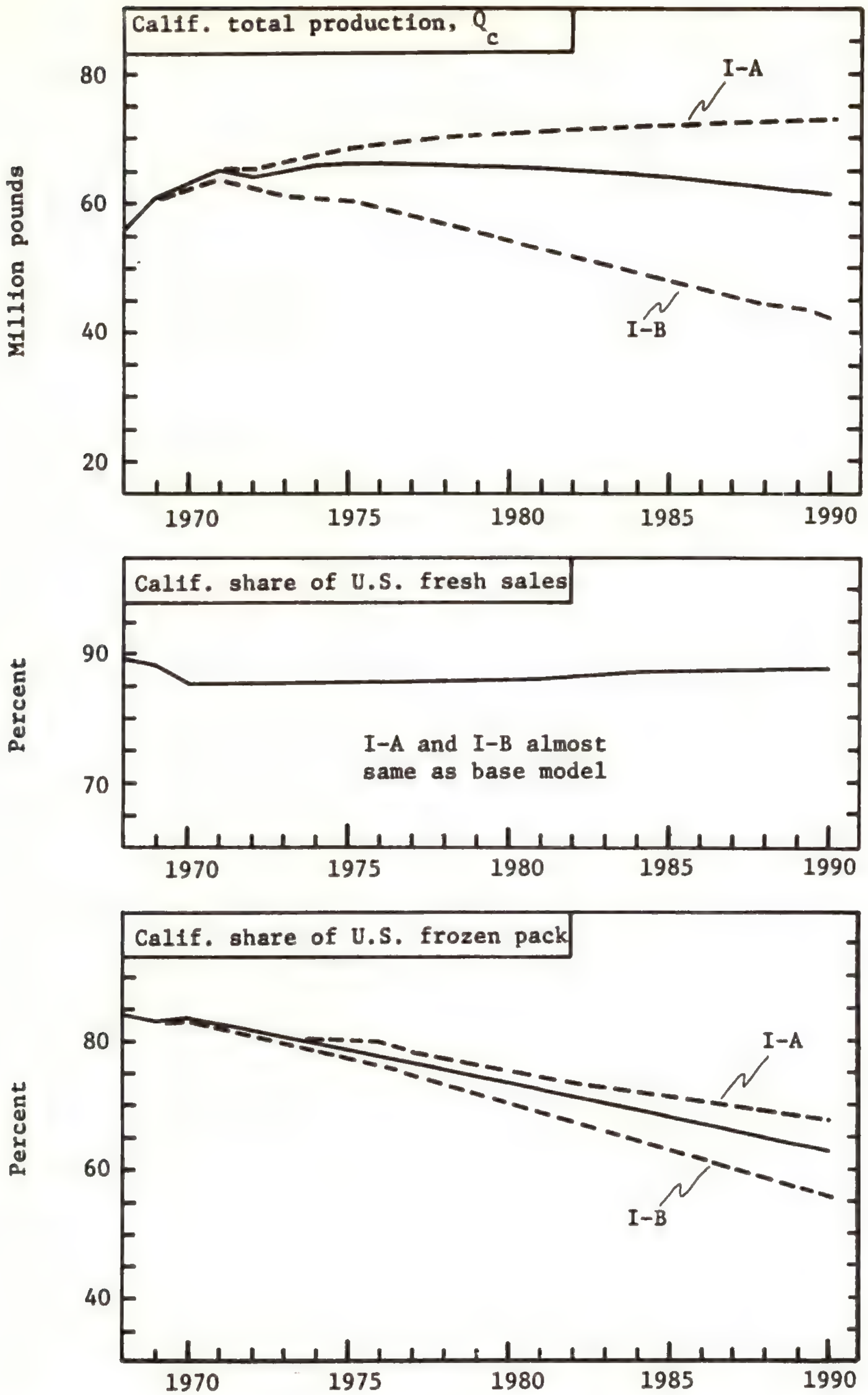

FIGURE 19-C

Simulation Experiment I. Projections of Total California Brussels Sprouts Production and California's Share of U.S. Fresh and Frozen Market Production

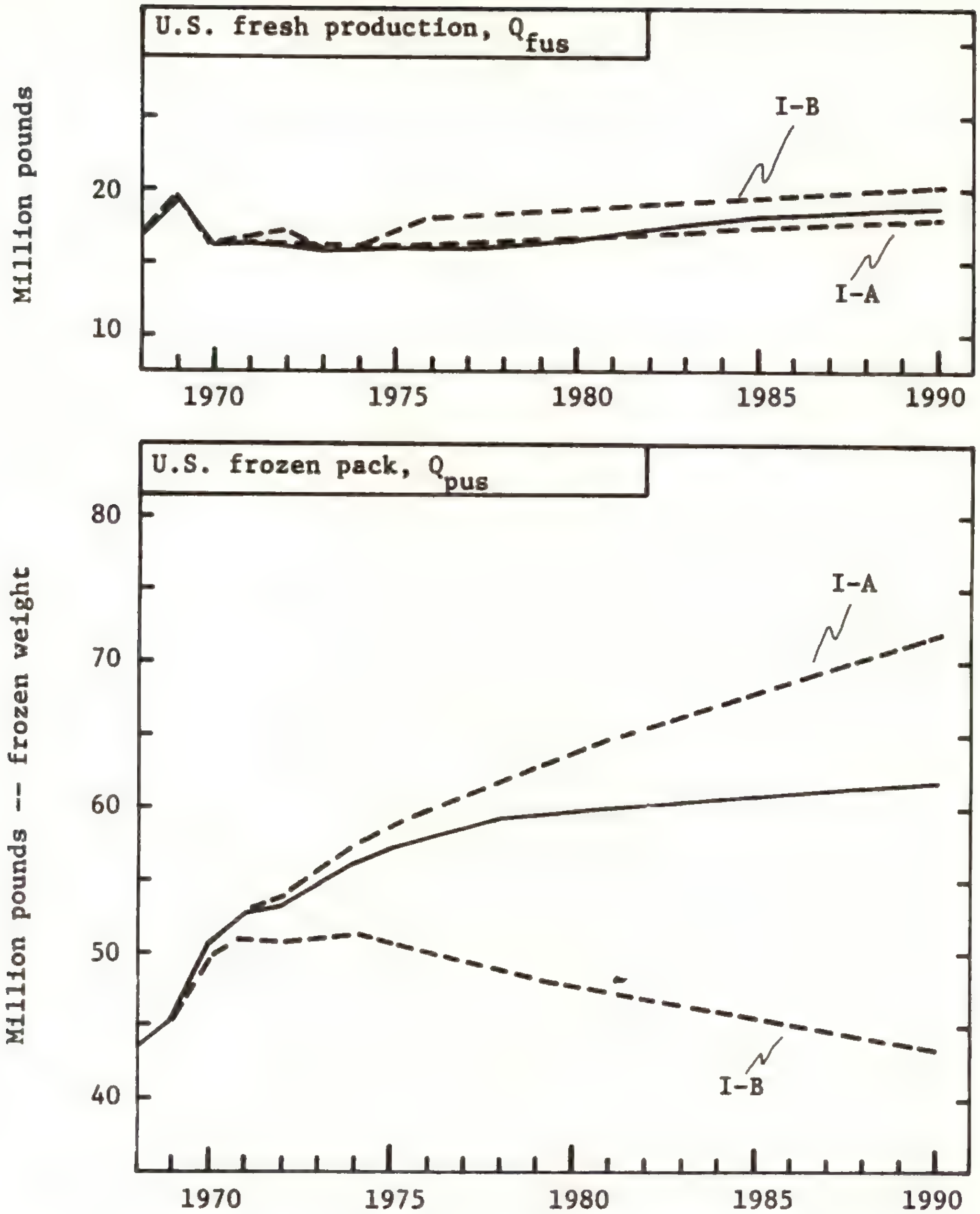

FIGURE 19-D

Simulation Experiment I. Projections of U.S. Brussels Sprouts Production for Fresh Market and Total Frozen Pack

variable (X_v) to increase at one-half the rate specified in the base model. Thus, $X_{vt} = X_{vt-1} + 0.248$. This allows the level of demand for Brussels sprouts to remain considerably higher than for the base model. Projecting competing products in this manner also serves as a proxy for other factors which might have a similar impact on demand. We shall refer to this as Model I-A.

The second demand change projected was to increase the index of U.S. per capita food expenditures (F) by 2 percentage points per year, rather than 3.2 as in the base model. All other variables remain as specified in the base model. This leads to a reduced level of demand. It would be equivalent, alternatively, to the original food expenditure projection, but with a decline in the coefficient of F. We shall refer to this as Model I-B.

Projections obtained with these two demand variations are compared with base model values in Figure 19.[1/] As might be expected, acreage and production tend to be higher for I-A, the higher demand, and lower for I-B. Several points seen particularly worthy of note. First, the level of fresh market production is not greatly influenced by these changes in demand. In fact, the lower level of demand leads to a slight increase in fresh market production as the frozen pack is adjusted downward more quickly than acreage.

Second, under competitive conditions, the price received by growers is not greatly affected, cost being the main long-run determinant. With increasing demand, however, grower prices tend to run slightly on the high side of the base model projection during the first decade (although not evident in the scale of the diagram). For relative decreases in demand as in I-B the grower price is slightly below the base model value during the first decade and then becomes about the same. The deviations shown in Table 10 do not bring this out clearly since P_{gc} is an average of the fresh and processed price, which is affected by the proportions allocated

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1/ Other variations were also run through the computer--for example, the lower projection of competing products, as in I-A, coupled with the lower projection of per capita food expenditures as in I-B. Since the latter tend to be offsetting, the results were similar to the base model. The two cases illustrated bring out the major points of concern.

to the two outlets. The price impact is somewhat greater for the prices received by freezers (P_{pc}).[1/]

A third point pertains to the impact on the California share of the frozen market. The relatively lower demand of I-B leads not only to a reduced frozen pack in California but to a further decline in its share of total U.S. production. With reduced demand it is possible, of course, that the upward trend in other region production would be reduced. This would tend to shift the I-B curves back a bit toward the base model.

Our comparative projections are possibly somewhat extreme. Intermediate projections of demand levels would produce changes intermediate between those shown and the base model. The experiment suggests, however, that the continued existence of the frozen Brussels sprouts industry on a significant level in California may be quite sensitive to changes in the level of demand for the product. Continuation of past trends in competing products, coupled with lessened effects of income changes, could produce rather large changes in production.

Effects of Changes in Competing Supplies

The earlier discussion of changes in the Brussels sprouts economy noted the increasing production of frozen sprouts in regions other than California. The base model continues the trend in other region production as observed during the period 1958-1967. This experiment investigates the effects on California production and returns of alternative rates of growth of production in other regions. In this case we include in "other regions" imports from Mexico or elsewhere, as well as United States production.

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1/ In actual practice, some of the price decrease experienced by processors under I-B might be passed back to producers. This does not happen in these projections since we have restricted the long-run grower price to be at least equal to our measure of growing cost. A floor could have been imposed on the freezer price as well, thus keeping both freezer and grower prices more closely in line with costs. With this restriction, frozen sales would have been reduced and freezer raw product demand lowered by the loss of sales and the added pressure of larger inventories. An administered price system which would impose such restrictions conceivably could be less painful to the industry during periods of decreasing demand than a free supply response to market experience. Similar comments apply to Experiments IV-A and IV-B to be discussed.

Projections for three situations are illustrated in Figure 20. Model II-A represents a low competitive case. It projects other region frozen pack to remain constant at seven million pounds per year. All other variables are as in the base model. This is the most favorable situation for California that seems at all possible. As might be expected, it leads to substantial increases in California acreage and frozen pack. It also results in a small increase in the level of California freezer prices relative to the base model. There is relatively little impact on the trend value of grower prices. The latter tend to converge toward and ultimately to be determined primarily by cost considerations. With reduced competition, however, there is less downward pressure on California grower prices and they remain slightly above the base model values.

Note that with Model II-A California fresh market production shows little change relative to the base model, nor does total U.S. frozen pack. California's share of the U.S. frozen pack remains high at 86 to 89 percent compared with a drop to 63 percent for the base model.

A variation of II-A, not illustrated maintained the ratio of other region to California frozen pack at the 1968 level of .192. This condition results in other region frozen pack increasing to 10 million pounds by 1990 (as compared to 7 million for II-A), with correspondingly lower California pack and acreage. The results are in other respects similar to II-A.

Model II-B shows what might happen if other region production or imports increased at a rate one-half million pounds higher than for the base model. The projection of Q_{po} then would be:

$$Q_{pot} = Q_{pot-1} + 1.229.$$

The effect of such an increase, if continued over the full interval, would be to drop California acreage to about 4,200 acres and California frozen pack to about 28.5 million pounds (Figure 20-A). California's share of frozen pack drops to 46 percent. Other variables, including U.S. production, show little relative change.

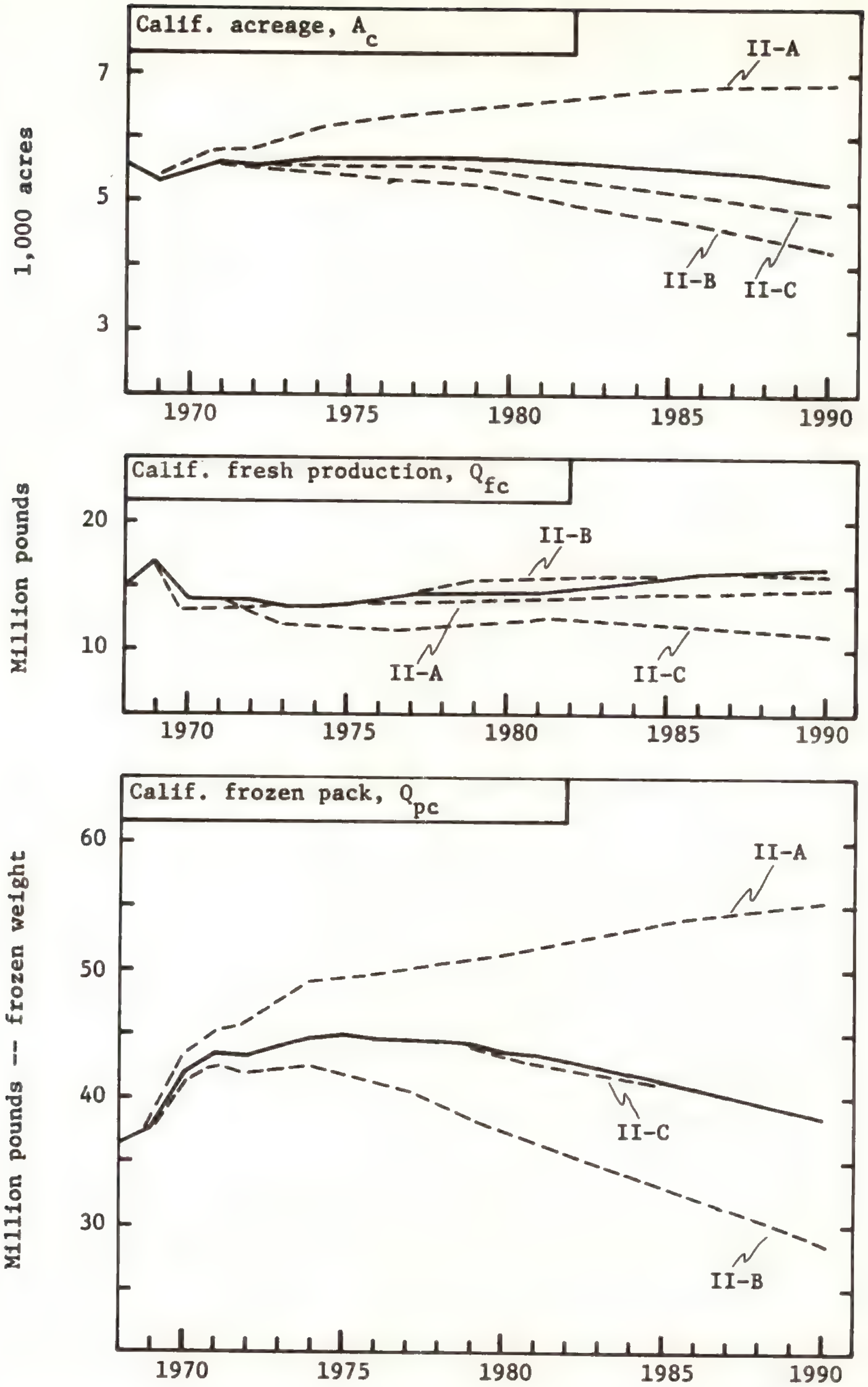

FIGURE 20-A

Simulation Experiment II. Projections of California Acreage, Fresh Market Production, and Frozen Pack

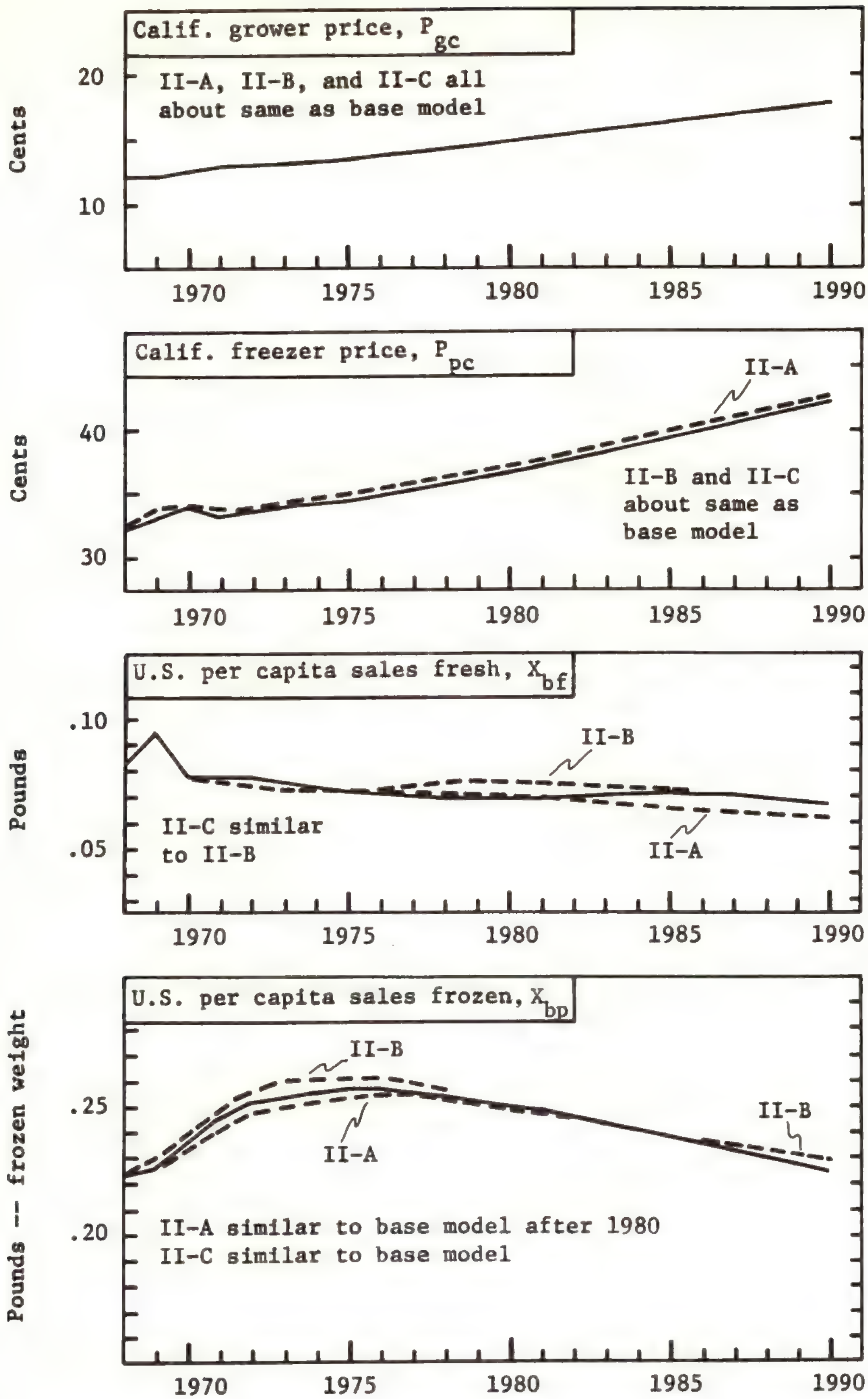

FIGURE 20-B

Simulation Experiment II. Projections of Average California Grower Price, F.O.B. Freezer Price, and Per Capita Disappearance of Fresh and Frozen Brussels Sprouts

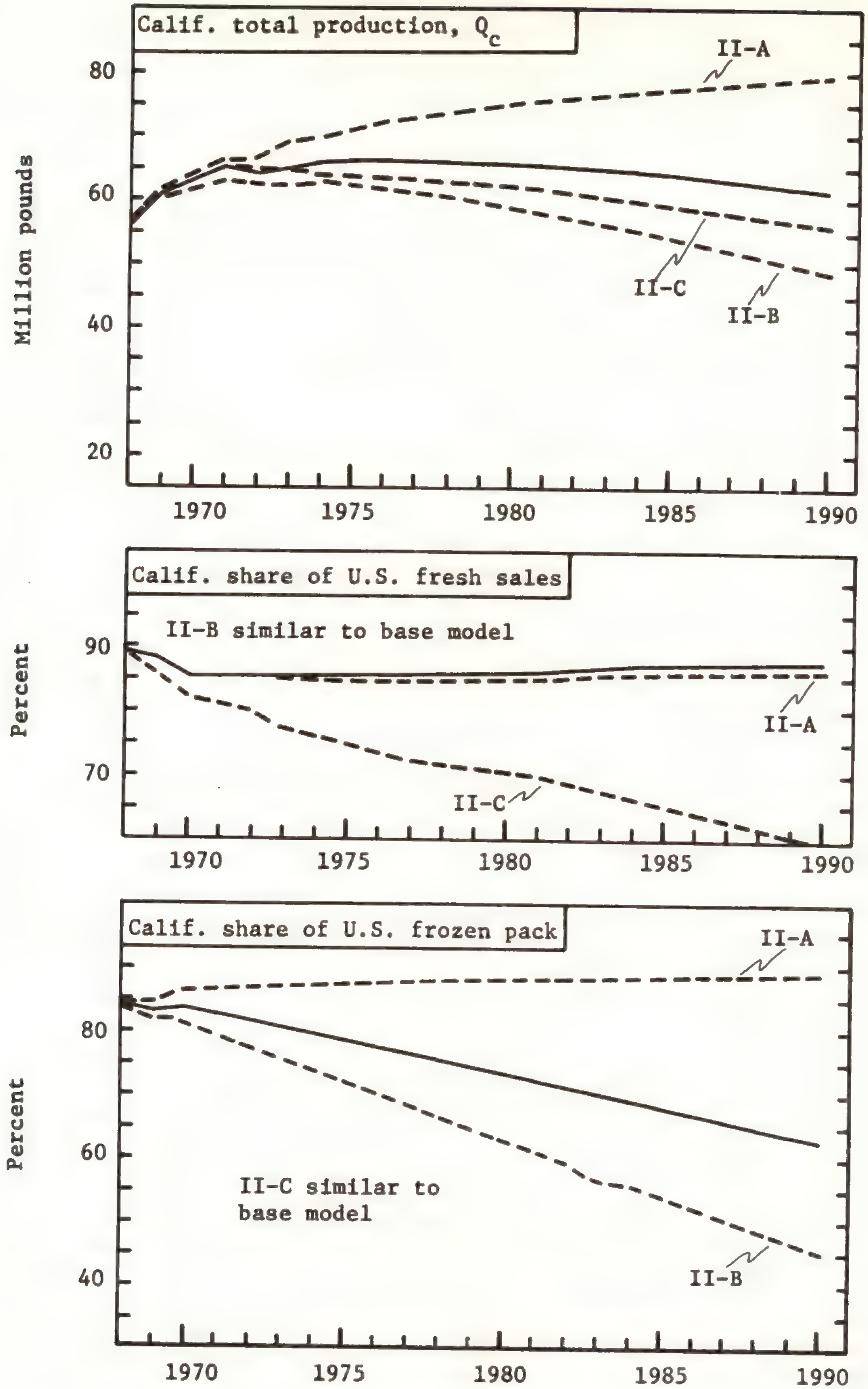

FIGURE 20-C

Simulation Experiment II. Projections of Total California Brussels Sprouts Production and California's Share of U.S. Fresh and Frozen Market Production

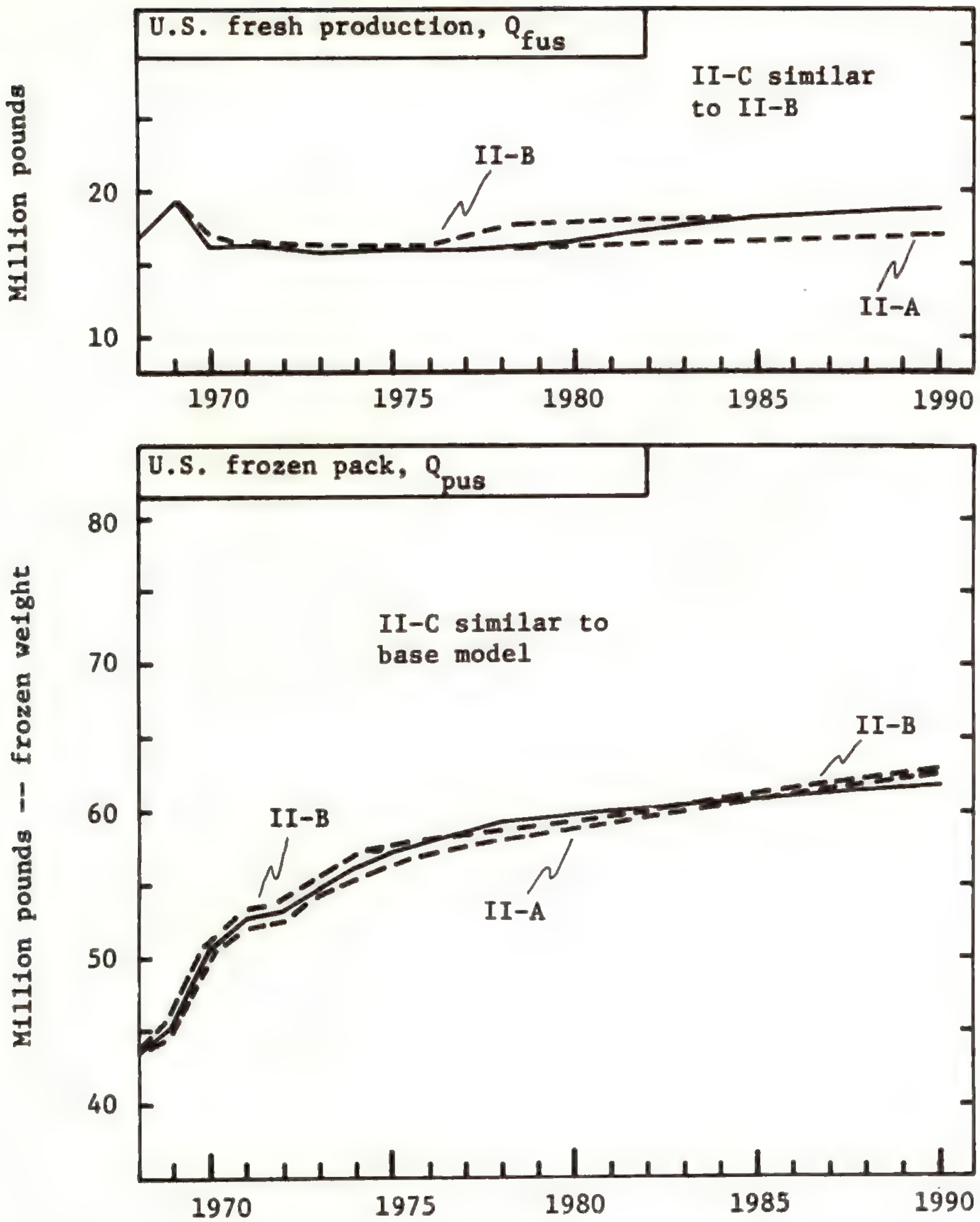

FIGURE 20-D

Simulation Experiment II. Projections of U.S. Brussels Sprouts Production for Fresh Market and Total Frozen Pack

A variation of II-B (not illustrated), added 2 million pounds of other region pack (rather than 0.5) for 5 years starting in 1970, then stopped except for the base model trend. The effect was to speed up the changes illustrated by II-B, but with the final long-run adjustment in 1990 similar to II-B.

The final situation considered in Experiment II pertains to the fresh market component of production. There has been no clear trend in other region production of Brussels sprouts for fresh market, and fresh imports from Mexico occur primarily during the period when there is little U.S. production. Therefore, the base model held other region fresh market production constant at the 1963-1967 average level of 2.34 million pounds. It is possible, of course, that fresh production in other U.S. regions or directly competing imports could increase. To investigate the potential impact of such a change we arbitrarily let "other region" fresh production increase annually by an amount equal to ten percent of the base model initial value. That is,

$$Q_{fot} = Q_{fot-1} + 0.234$$

where $Q_{fo} = 2.34$ in 1967. All other exogenous variables are projected as in the base model. The effects of this increase are illustrated by lines II-C in Figure 20.

The main result is that California acreage decreases by about 9 percent relative to the base model and California production for fresh market is reduced nearly one-third by 1990. California's share of the fresh market drops to about 60 percent, compared with 87 percent in the base model. The other economic variables in the system are largely unaffected.

Effects of Changes in Technology

Our third experiment investigates the potential impact of changes in cultural practices, harvesting methods, and processing techniques which could possibly reduce costs to lower levels than projected in the base model. Three basic situations were considered, each with some variations.

Model III-A assumes a rate of technological development in production and harvesting which reduces costs by one percent per year relative to the base model. That is,

$$C_{gct} = (.99)(1.02)C_{gct-1} = 1.01\ C_{gct-1}.$$

The net result is that costs still increase because of inflationary pressures, but at one percent per year rather than two percent as in the base model. Figure 21 shows that under these conditions California acreage and total Brussels sprouts production gradually increase above the base model projection, achieving a level about 20 percent higher by 1990. Since prices are heavily influenced by costs, both the average grower price and the processor price fall below the base model projection. With the reduced rate of cost increase, average returns to both growers and processors remain slightly more favorable than in the base model.

The lower prices realized with Model III-A lead to increased per capita consumption of both fresh and frozen sprouts, relative to the base model. California's market shares are also maintained at a higher level, although the deviation from the base model is not large.

Two variations of III-A, not illustrated, permitted increases in yield per acre of 100 and 200 pounds per year. The main effect was to reduce the level of acreage by up to 12 percent in the first case and up to 26 percent in the second relative to III-A. In both cases total California production rose only slightly above the III-A level. Quantities allocated to the fresh market were increased about 13 percent and frozen pack reduced a little less than 4 percent relative to III-A by the end of the period.

Model III-B restores the grower cost projection to the base model level and permits the processing cost to increase at a relatively lower rate. It was arbitrarily set a $C_{pct} = C_{pct-1} + 0.08$. This was the average rate of change in our measure of processing cost during the interval 1961-1967 and is approximately one-half the rate of increase projected for the base model. This model also results in an increase in acreage relative to the base model, but since the magnitude of the relative cost

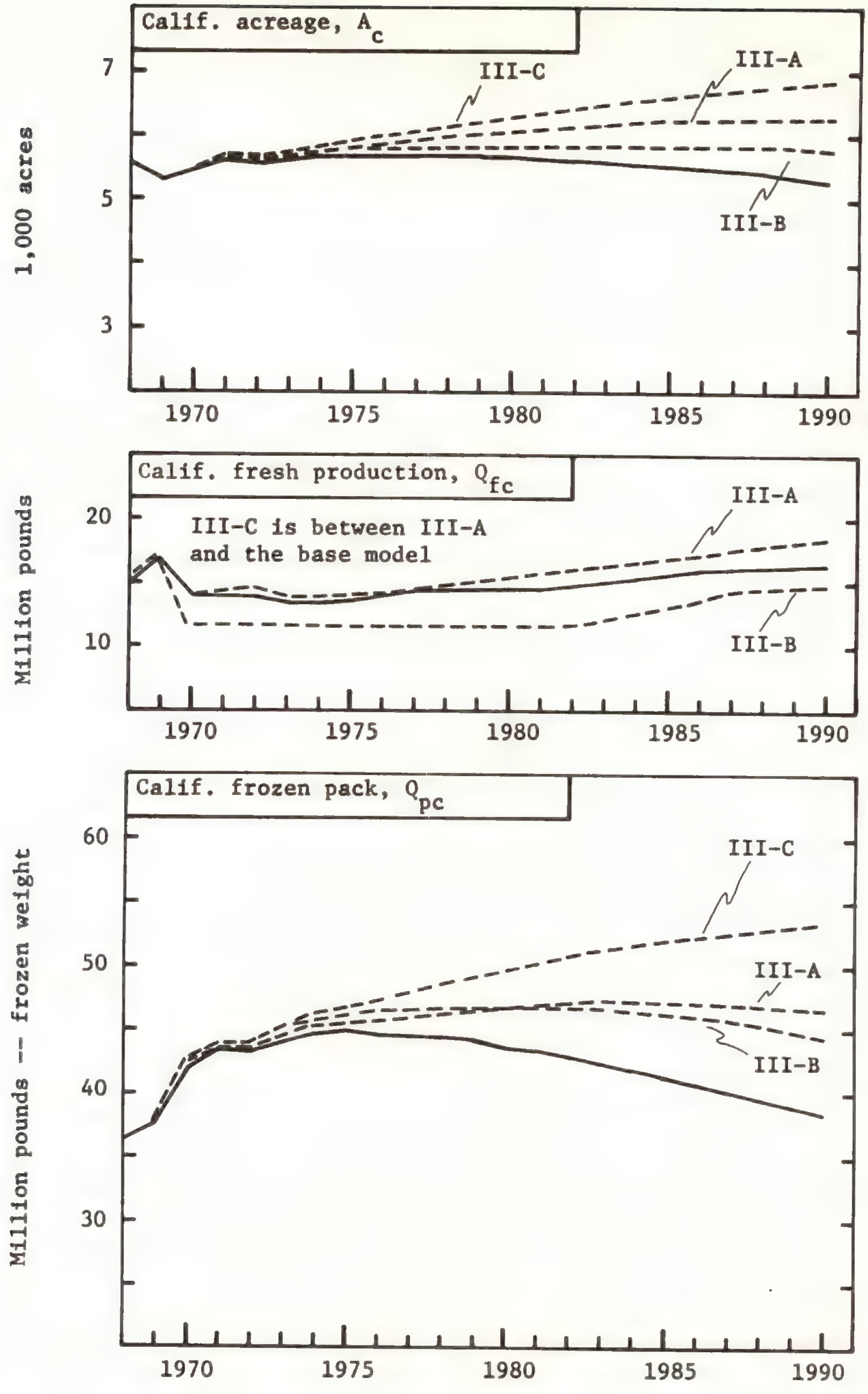

FIGURE 21-A

Simulation Experiment III. Projections of California Acreage, Fresh Market Production, and Frozen Pack

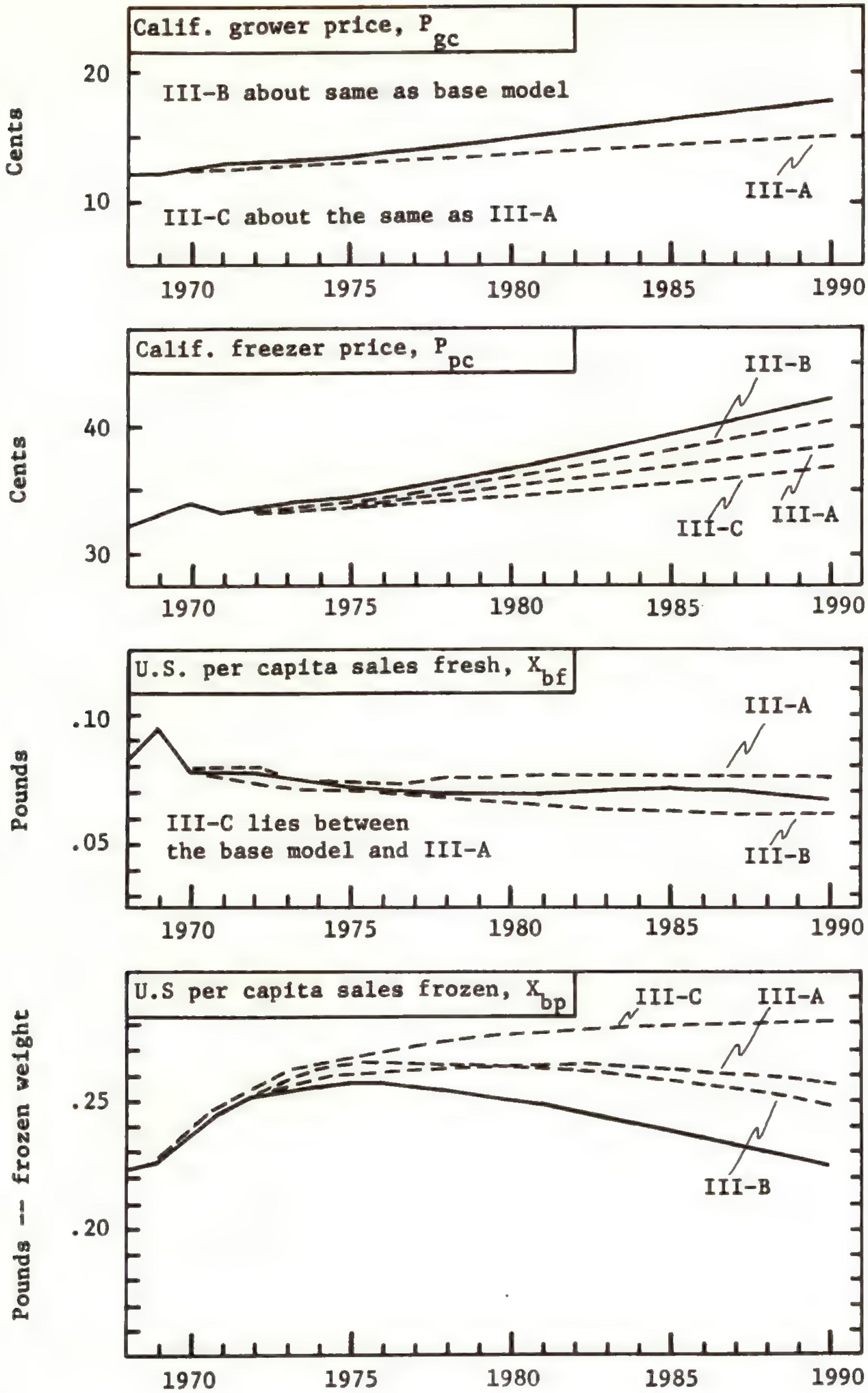

FIGURE 21-B

Simulation Experiment III. Projections of Average California Grower Price, F.O.B. Freezer Price, and Per Capita Disappearance of Fresh and Frozen Brussels Sprouts

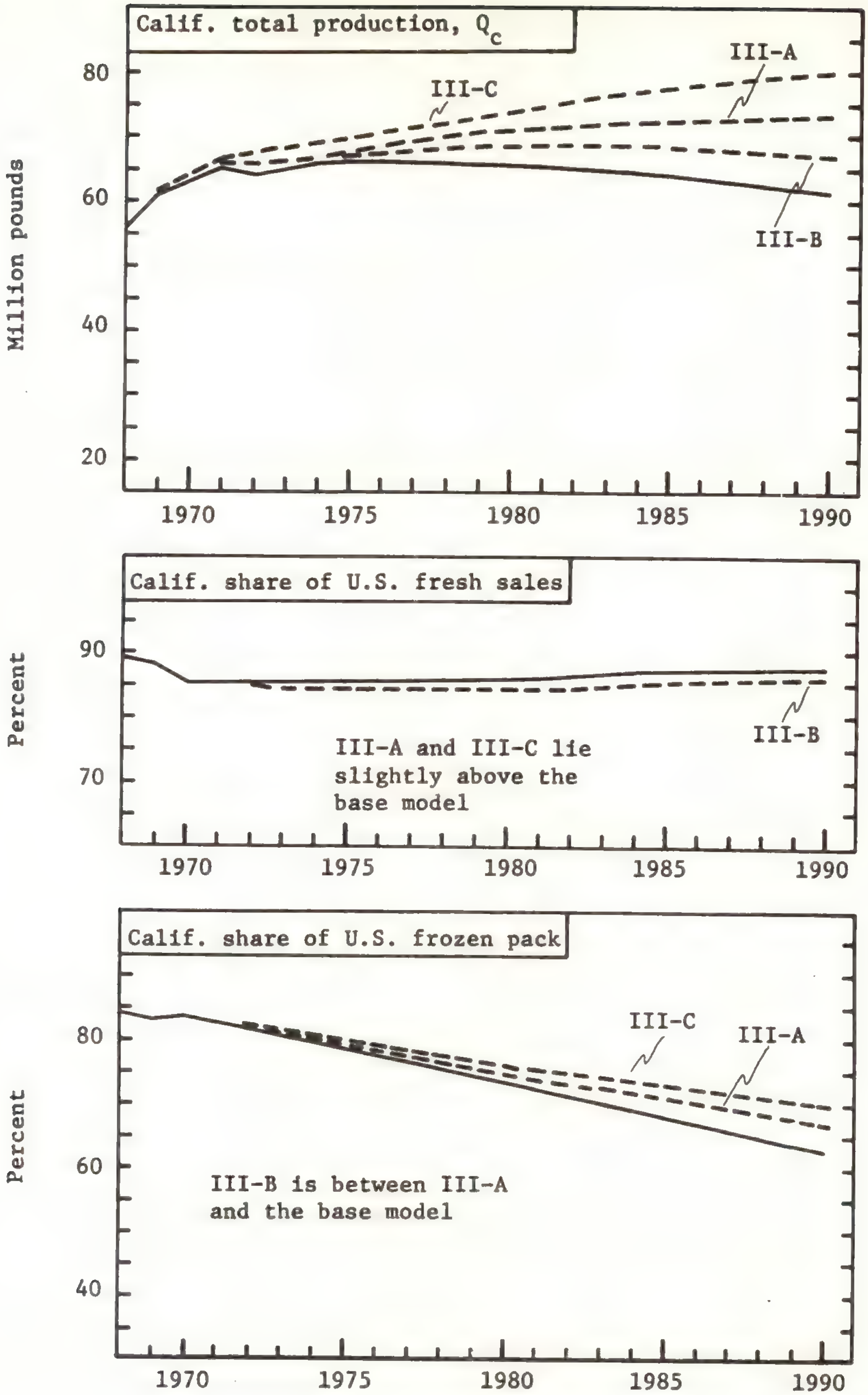

FIGURE 21-C

Simulation Experiment III. Projections of Total California Brussels Sprouts Production and California's Share of U.S. Fresh and Frozen Market Production

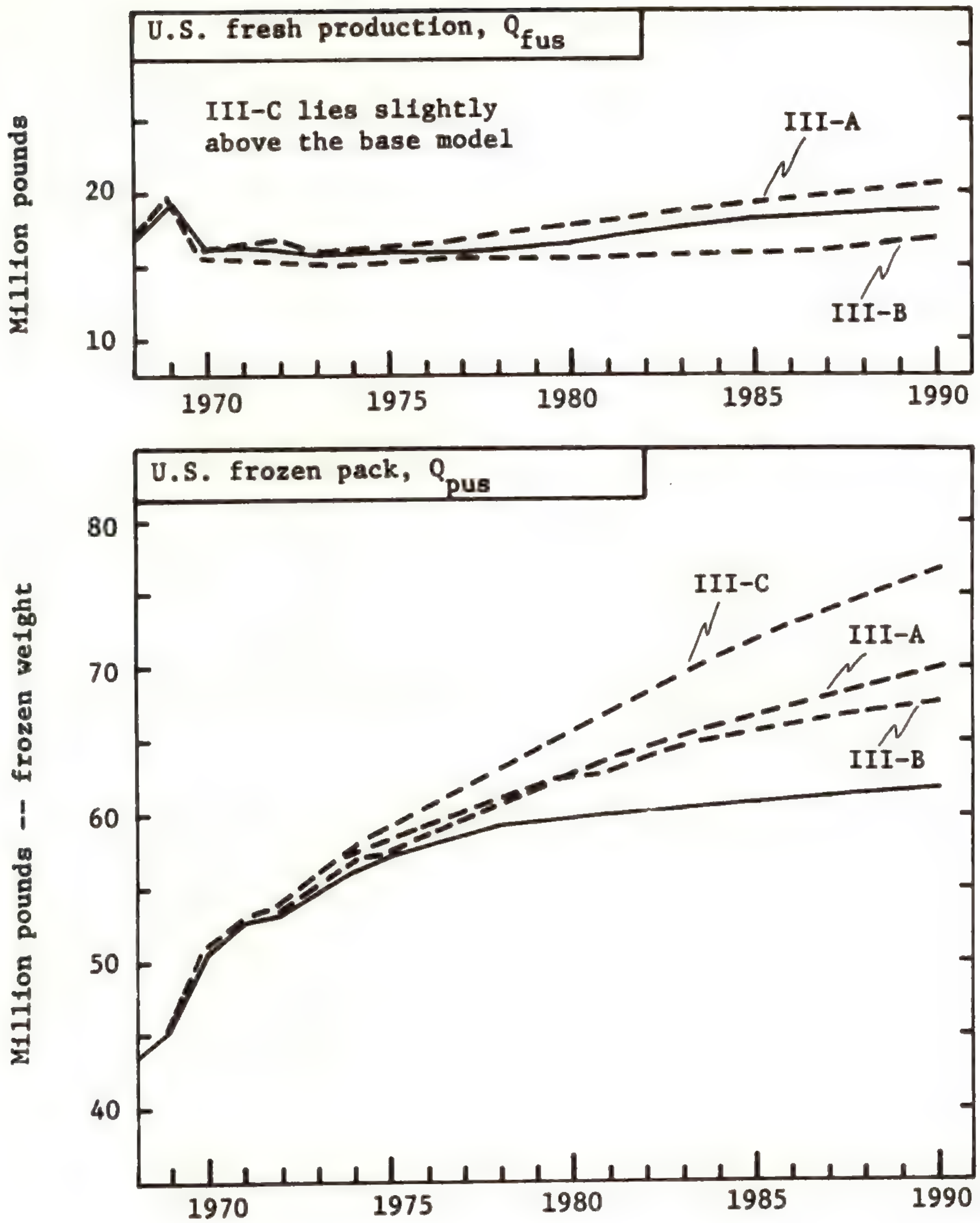

FIGURE 21-D

Simulation Experiment III. Projections of U.S. Brussels Sprouts Production for Fresh Market and Total Frozen Pack

reduction is less than for III-A, the acreage increase is also less (Figure 21-A). Note that in this case while total California production increases, the quantity allocated to the fresh market actually decreases. This is due to the relative increase in freezer demand for the raw product as a result of the relatively lower processing cost. The f.o.b. freezer price declines relative to the base model, while the grower price remains about the same. Market shares also differ little from the base model.

Model III-C combines the conditions projected in III-A and III-B. The effect is to increase California acreage by roughly the sum of the III-A and III-B increases, to raise fresh market production only slightly (compared with the base model), to greatly increase California frozen pack, to reduce prices (but not grower and freezer returns), to increase U.S. per capita frozen consumption, and to raise California's share of frozen pack somewhat above the base model value. These projections assume that other region production remains as specified in the base model. If other regions also experienced improvements in technology they might absorb some of the increases projected in Figure 21.

Effects of Changes in Marketing Policy

The last experiment inquires into the potential effects of alternative policies associated with the administration of the Marketing Program for Brussels Sprouts for Freezing. Two basic policy situations are considered: termination of the marketing program and increasing the restrictiveness of the program. The effects of each policy are examined for two alternative assumptions concerning the growth of frozen Brussels sprouts production in other regions.

Model IV-A drops the marketing program completely, with all other variables projected as in the base model. To accomplish this, the shift variable L is simply set at zero. This is the variable that was introduced to allow for a more restrictive attitude starting in 1958 as a result of the marketing order program. Setting it at zero assumes that grower allocation behavior would revert to the premarketing program situation. The effect is to shift the frozen pack prediction equation upward by about 12.5 percent--see Equation (20). The effects on production, acreage, and price projections are illustrated by lines IV-A in Figure 22.

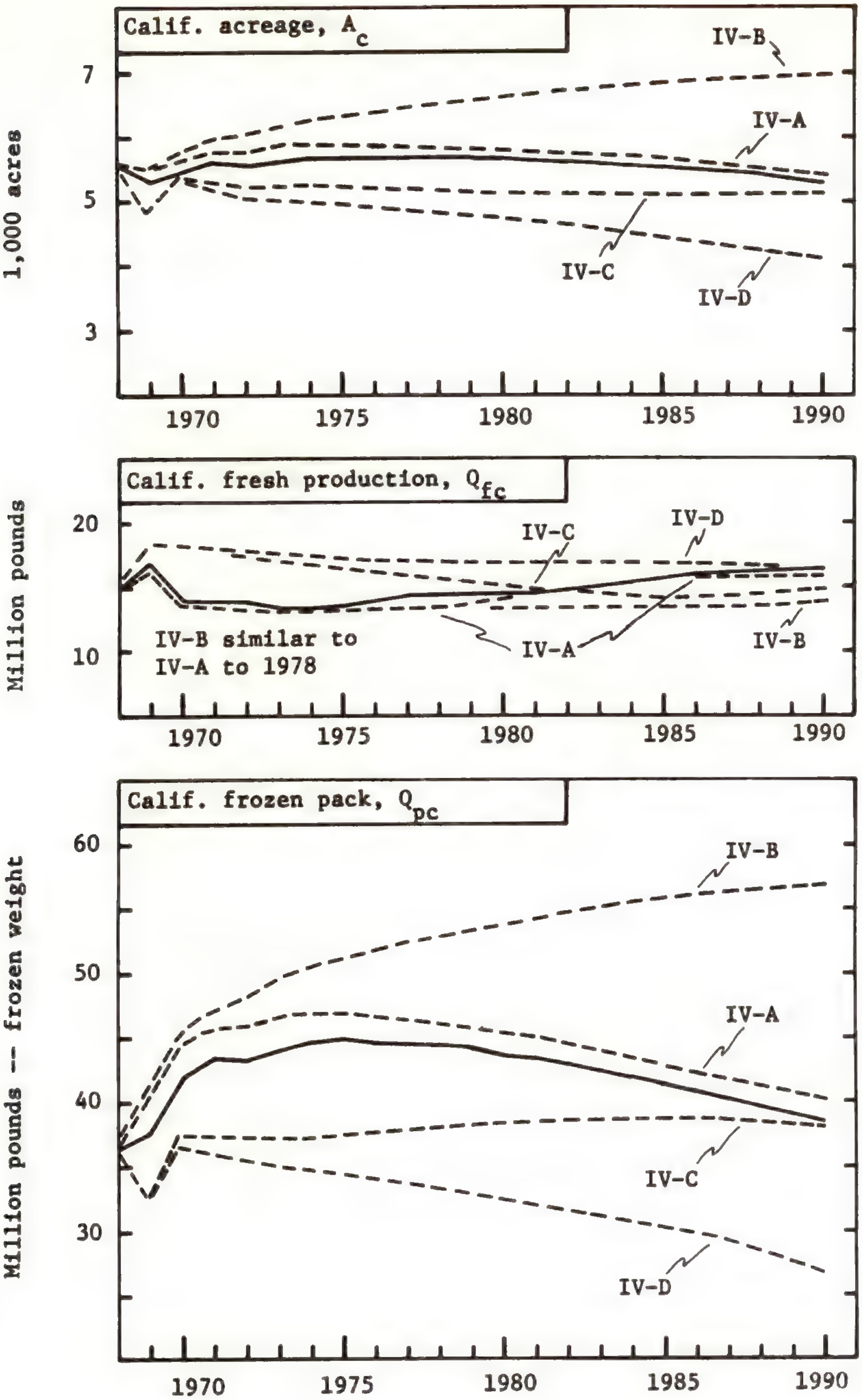

FIGURE 22-A

Simulation Experiment IV. Projections of California Acreage, Fresh Market Production, and Frozen Pack

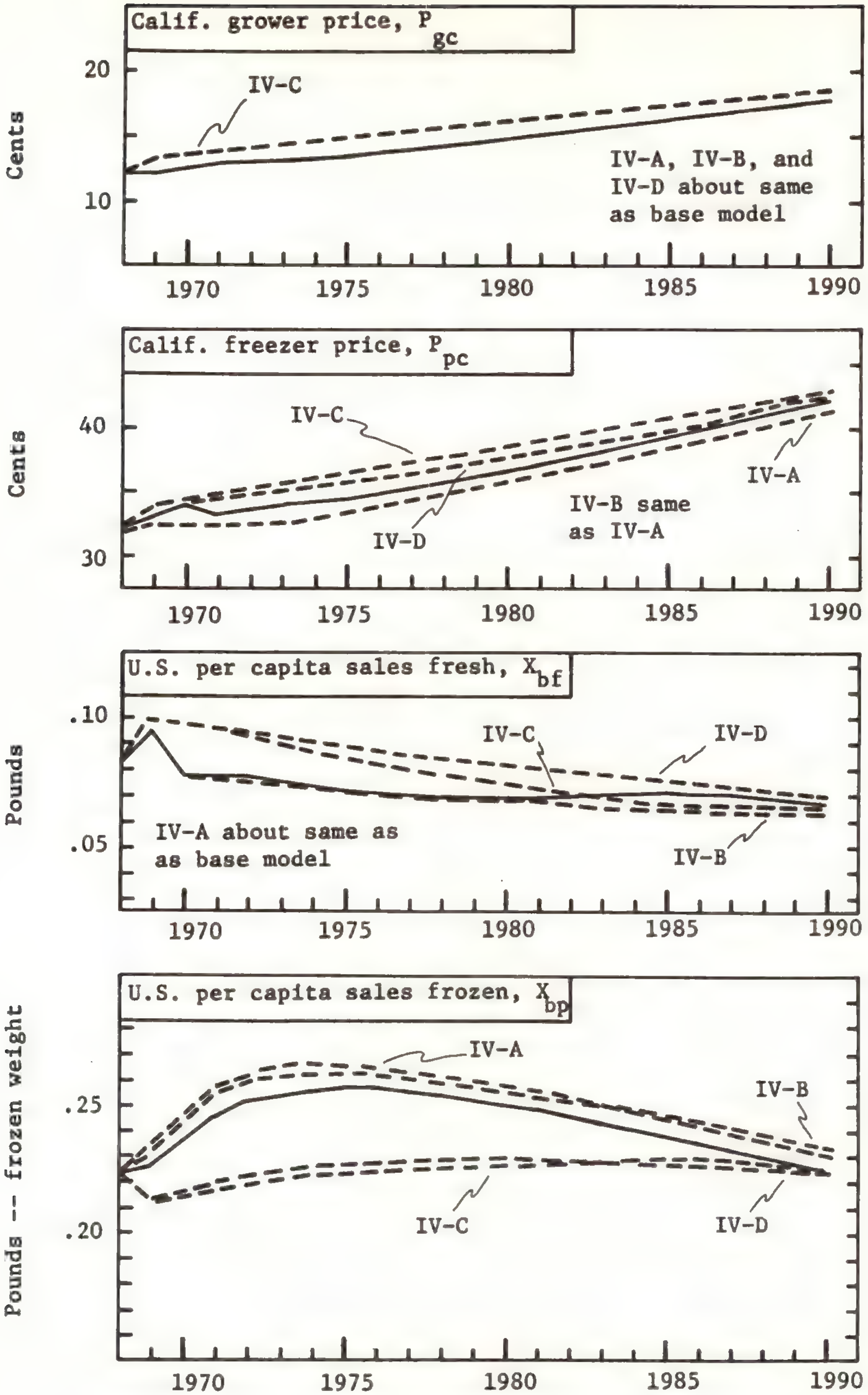

FIGURE 22-B

Simulation Experiment IV. Projections of Average California Grower Price, F.O.B. Freezer Price, and Per Capita Disappearance of Fresh and Frozen Brussels Sprouts

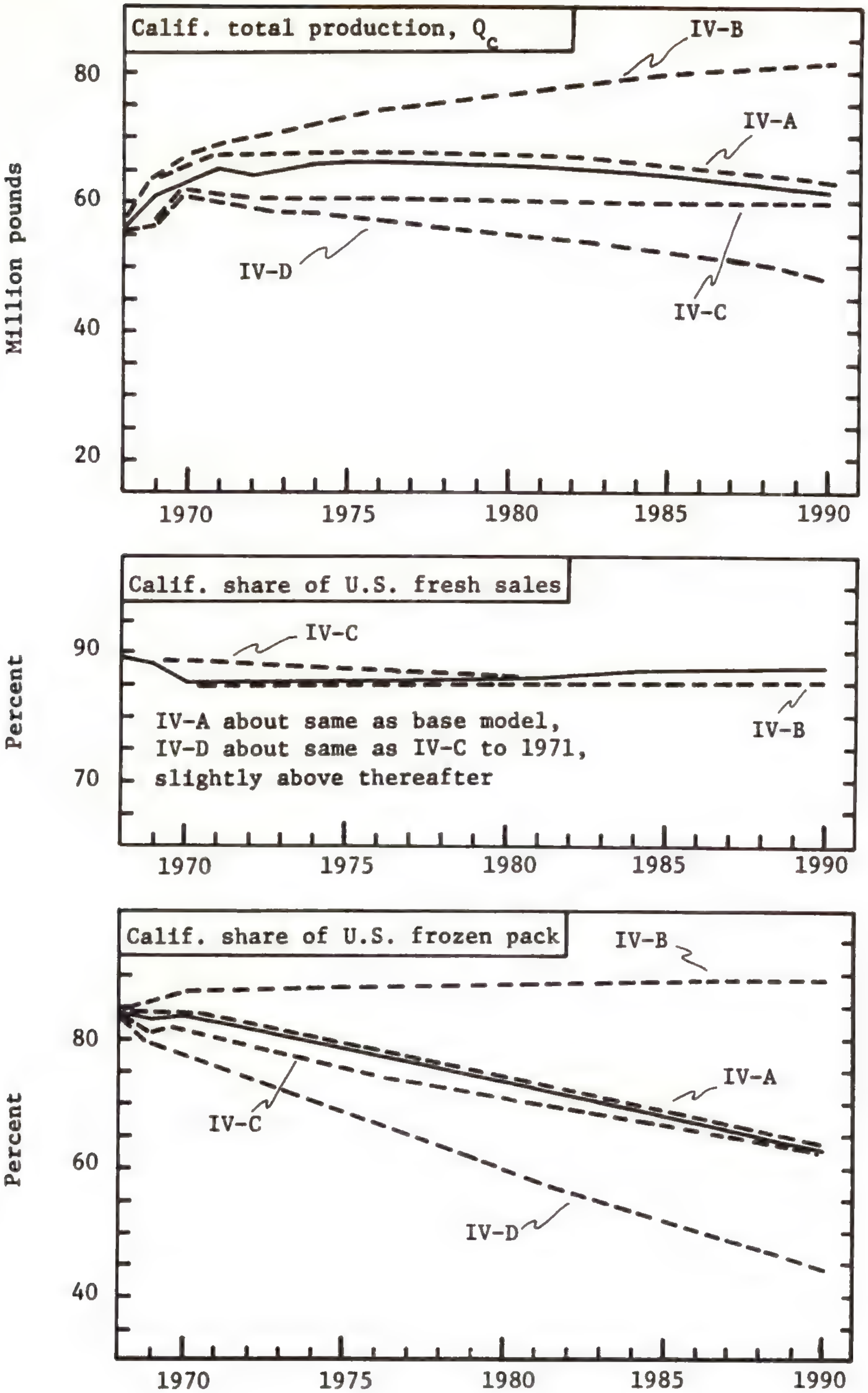

FIGURE 22-C

Simulation Experiment IV. Projections of Total California Brussels Sprouts Production and California's Share of U.S. Fresh and Frozen Market Production

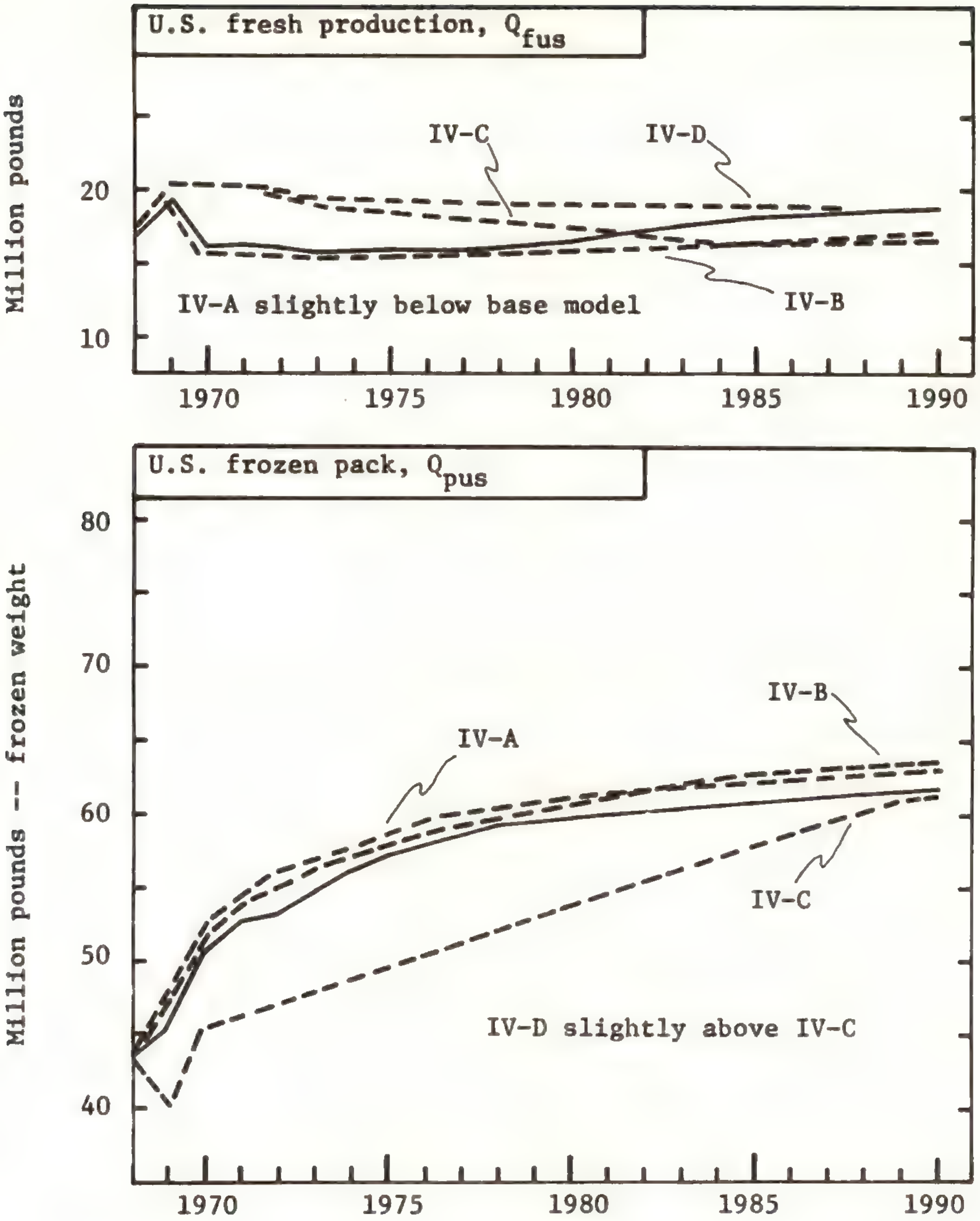

FIGURE 22-D

Simulation Experiment IV. Projections of U.S. Brussels Sprouts Production for Fresh Market and Total Frozen Pack

The immediate effect of dropping the marketing order program is an increase in frozen market production, a decrease in fresh market production, and decreases in both grower and freezer average prices relative to the base model. Following the initial shock, acreage and frozen pack are gradually adjusted toward the base model values and prices eventually approach the base model levels. Average profit levels for both the growers and processors are slightly below the base model projections, although the long-run difference is minor. The situation is a familiar one, illustrating the short-run problems that may be associated with abrupt termination of established control programs, even though the long-run impact may be small. Changes in the structure of competition among freezers could, of course, alter the demand for raw product and modify the projected pressure on freezer profit margins. This, however, would involve a change in the "rules of the game" under which our projections were made and therefore, does not invalidate the basic conclusions, which are conditional in nature.

With the termination of the marketing order program and increased California production, Brussels sprouts production might prove less attractive in other regions. To explore effects of such a situation we have recomputed the IV-A projections with other region production held at the level of seven million pounds (as in II-A). The results are illustrated by lines IV-B in Figure 22.

Such a reduction in competing production is perhaps somewhat extreme to attribute to the termination of the marketing order program, and IV-B might more properly be compared to II-A than with the base model. In either case, the principal effect is to greatly increase the acreage and production in California and eventually to reduce the pressure on prices and profit margins compared with IV-A. While total U.S. production is only slightly increased, California's share of this production remains quite high, approaching 89 percent. Although this situation seems much more favorable than IV-A, the favor rests mainly on the assumption of no increase in other region production--an assumption which could prove to be very unrealistic.

The alternative marketing policy considered is to make the program more restrictive than it has been. To explore this aspect we arbitrarily

set the value of the shift variable L at 2, with all other variables projected as in the base model. This, in effect, doubles the restrictiveness and lowers the level of the frozen pack predicting equation (Equation 20) by about 12.5 percent. Projections based on this assumption are illustrated by lines IV-C in Figure 22.

Model IV-C leads to an initial reduction in California's acreage and frozen pack, an increase in production allocated to the fresh market, and higher grower and freezer prices, relative to the base model. California's share of the frozen pack decreases slightly and the fresh market share shows a small increase. As the 1990 horizon approaches, the values of these variables tend to approach the base model values.

An important factor to be considered in applying a more restrictive policy is the possibility that the associated higher prices and reduced supplies will stimulate increased production in other regions. If we had been able to estimate supply response equations for other regions the result could have been generated directly in the IV-C Model. Since we could not, we have explored the possibility of increased competition from other regions by increasing such production by one-half million pounds per year over the base model, as in II-B. The resulting projections are illustrated by lines IV-D in Figure 22.

The effect of IV-D is to reduce greatly the California acreage and allocation to freezing and to increase the allocation to the fresh market slightly over IV-C. Both grower and processor prices still remain above the base model values, although not as high as for IV-C. However, California growers pay a substantial price for their higher unit returns since their share of frozen pack drops to only about 44 percent by 1990, with only about 4,100 acres left in production.

Summary and Overview of the Simulation Experiments

The entire set of simulation experiments is presented in summary form in Table 10. The top line of the table gives the specific values of the base model projections of each of the key endogenous variables for 1970,

TABLE 10

Summary of the Simulation Experiments

Experimental model	Values of endogenous variables[a/]								
	California acreage (A_c)			California fresh sales (Q_{fc})			California frozen pack (Q_{pc})		
	1970	1980	1990	1970	1980	1990	1970	1980	1990
	acres			million pounds			million pounds		
Base model	5,447	5,666	5,306	13.8	14.3	16.3	42.1	43.9	38.6
	Deviations from base model								
<u>Experiment I (Change in Demand)</u>									
I-A: Low X_v (increased demand)	12	441	985	0.2	0.3	- 0.5	0	4.1	10.2
I-B: Low F (reduced demand)	- 91	- 987	-1,664	- 0.1	2.1	1.6	- 0.7	-11.6	-17.8
<u>Experiment II (Change in Competing Supplies)</u>									
II-A: Reduced competition, frozen	91	808	1,543	0.1	- 0.2	- 1.5	0.8	8.2	16.5
II-B: Increased competition, frozen	- 63	- 533	-1,038	0	1.3	- 0.2	- 0.9	- 6.4	-10.1
II-C: Increased competition, fresh	- 41	- 210	- 446	- 0.4	- 1.8	- 5.2	0	- 0.5	0
<u>Experiment III (Change in Technology)</u>									
III-A: Improved production technology	17	411	994	0.2	1.3	2.0	0.1	3.0	8.2
III-B: Improved processing technology	19	214	473	- 0.1	- 1.0	- 1.6	0.3	2.9	6.1
III-C: Both production and processing technology improved	37	642	1,548	0.1	0.5	0.4	0.3	5.9	15.0
<u>Experiment IV (Change in Market Policy)</u>									
IV-A: Market order terminated	227	149	128	0.2	- 0.2	- 0.4	2.1	1.7	1.6
IV-B: Market order terminated and low competition	337	953	1,677	0.3	- 0.7	- 1.8	3.1	9:9	18.2
IV-C: Increased restrictions	- 102	- 478	- 143	4.2	0.9	- 1.3	- 4.6	- 5.5	- 0.3
IV-D: Increased restrictions and increased competition	- 174	- 900	-1,167	4.0	2.6	0.2	- 5.1	-11.1	-11.7

Experimental model	Values of endogenous variables[a/]								
	U.S. fresh market sales (Q_{fus})			U.S. frozen pack (Q_{pus})			Average California grower price (P_{gc})		
	1970	1980	1990	1970	1980	1990	1970	1980	1990
	million pounds			million pounds			cents per pound		
Base model	16.2	16.7	18.6	50.6	59.6	61.6	12.8	15.0	18.0
	Deviations from base model								
<u>Experiment I (Change in Demand)</u>									
I-A: Low X_v (increased demand)	0.1	0.2	- 0.5	0	4.1	10.3	0	0	0.2
I-B: Low F (reduced demand)	- 0.2	2.0	1.6	- 0.8	-11.5	-17.8	0	- 0.1	0.2
<u>Experiment II (Change in Competing Supplies)</u>									
II-A: Reduced competition, frozen	0.1	- 0.3	- 1.4	- 0.7	- 0.5	0.5	0.1	0	0.2
II-B: Increased competition, frozen	- 0.1	1.2	- 0.2	0.4	- 0.3	1.0	0	- 0.2	0.1
II-C: Increased competition, fresh	0	0.9	0	0	- 0.5	0	0	- 0.2	0
<u>Experiment III (Change in Technology)</u>									
III-A: Improved production technology	0.1	1.2	2.0	0	3.0	8.2	0	- 1.4	- 3.2
III-B: Improved processing technology	- 0.1	- 1.0	- 1.6	0.3	2.9	6.1	0.1	0	0
III-C: Both production and processing technology improved	0	0.5	0.4	0.3	5.9	15.0	0	- 1.4	- 3.3
<u>Experiment IV (Change in Market Policy)</u>									
IV-A: Market order terminated	0.1	- 0.3	- 0.4	2.1	1.7	1.6	- 0.4	- 0.1	0
IV-B: Market order terminated and low competition	0.3	- 0.7	- 1.8	1.6	1.2	2.2	- 0.4	- 0.1	0.1
IV-C: Increased restrictions	4.2	0.8	- 1.2	- 4.6	- 5.5	- 0.3	1.0	1.0	0.3
IV-D: Increased restrictions and increased competition	4.0	2.5	0.2	- 4.2	- 5.1	- 0.7	0.9	0.5	0.1

(Continued on next page.)

Table 10 continued.

Experimental model	Values of endogenous variables[a/]: Total California production (Q_c) 1970	1980	1990	California share of U.S. fresh sales ($Q_{fc} \div Q_{fus}$)100 1970	1980	1990	California share of U.S. frozen pack ($Q_{pc} \div Q_{pus}$)100 1970	1980	1990
	million pounds			percent			percent		
Base model	63.2	65.7	61.6	86	86	87	83	74	63
	Deviations from base model								
Experiment I (Change in Demand)									
I-A: Low X_v (increased demand)	0.1	5.1	11.4	0	0	- 1	0	1	5
I-B: Low F (reduced demand)	- 1.1	-11.4	-19.4	- 1	2	1	0	- 7	-16
Experiment II (Change in Competing Supplies)									
II-A: Reduced competition, frozen	1.0	9.4	17.8	0	0	- 1	3	14	26
II-B: Increased competition, frozen	- 0.7	- 6.9	-12.1	0	1	0	- 1	-11	-17
II-C: Increased competition, fresh	- 0.4	- 2.4	5.2	- 3	-15	-27	0	- 1	0
Experiment III (Change in Technology)									
III-A: Improved production technology	0.2	4.8	11.5	0	1	2	0	1	4
III-B: Improved processing technology	0.2	2.5	5.4	0	- 1	- 1	0	1	3
III-C: Both production and processing technology improved	0.4	7.5	17.9	0	0	1	0	2	7
Experiment IV (Change in Market Policy)									
IV-A: Market order terminated	2.6	1.8	1.4	0	0	0	1	0	1
IV-B: Market order terminated and low competition	3.9	11.1	19.4	0	0	- 1	3	15	26
IV-C: Increased restrictions	- 1.2	- 5.5	- 1.7	3	1	0	- 1	- 3	- 1
IV-D: Increased restrictions and increased competition	- 2.0	-10.4	13.6	2	2	1	- 3	-14	-19

Experimental model	Values of endogenous variables[a/]: California f.o.b. processor price (P_{pc}) 1970	1980	1990	U.S. per capita sales, fresh (X_{bf}) 1970	1980	1990	U.S. per capita sales, frozen (X_{bp}) 1970	1980	1990
	cents per pound			pounds			pounds		
Base model	33.9	36.7	42.3	.078	.070	.068	.236	.251	.226
	Deviations from base model								
Experiment I (Change in Demand)									
I-A: Low X_v (increased demand)	0.2	0.6	0.7	.001	.001	-.002	0	.016	.037
I-B: Low F (reduced demand)	- 0.7	- 1.3	- 1.9	-.001	.009	.006	-.002	-.047	-.065
Experiment II (Change in Competing Supplies)									
II-A: Reduced competition, frozen	0.3	0.3	0.3	0	-.001	-.005	-.003	-.002	.002
II-B: Increased competition, frozen	- 0.1	- 0.2	- 0.3	0	.005	-.001	.002	-.001	.003
II-C: Increased competition, fresh	0	- 0.1	0	0	.003	0	0	-.002	0
Experiment III (Change in Technology)									
III-A: Improved production technology	0	- 1.4	- 3.7	.001	.006	.008	0	.012	.029
III-B: Improved processing technology	0	- 0.7	- 1.9	0	-.004	-.006	.001	.012	.022
III-C: Both production and processing technology improved	- 0.1	- 2.1	- 5.5	0	.003	.002	.001	.023	.054
Experiment IV (Change in Market Policy)									
IV-A: Market order terminated	- 0.9	- 0.5	- 0.5	.001	-.001	-.001	.010	.007	.006
IV-B: Market order terminated and low competition	- 0.7	- 0.2	- 0.2	.001	-.002	-.006	.007	.006	.008
IV-C: Increased restrictions	0.8	2.1	0.7	.020	.004	-.004	-.021	-.024	-.002
IV-D: Increased restrictions and increased competition	0.6	1.4	0.3	.019	.011	.001	-.019	-.022	-.003

a/ For reference purposes, the actual 1968 values of these variables were as follows: A_c = 5,600, Q_{fc} = 15.1, Q_{pc} = 36.4, P_{gc} = 12.2, P_{pc} = 32.3, X_{bf} = .083, X_{bp} = .236, Q_c = 56.0, ($Q_{fc} \div Q_{fus}$)100 = 89.4, ($Q_{pc} \div Q_{pus}$)100 = 83.3, Q_{fus} = 16.9, Q_{pus} = 43.4.

1980, and 1990. The remaining figures show the deviations of each of the experimental situations from the base model values.

The base model approach was adopted because of the infinite number of situations which conceivably could be considered. This procedure permits us to vary one thing at a time and assess its relative impact. Situations which would vary two or three things at a time could also be of interest. For example, we might ask what happens if we combine reduced demand with improved technology and a more restrictive marketing policy. Although the results of varying single variables are not directly additive, rough indications of combined effects of several changes may be obtained by comparing and combining projections among the several experiments. This is accomplished rather easily with reference to Table 10. For example, increased demand as in I-A coupled with improved production technology as in III-A could lead to an increase of roughly 800 acres in California by 1980 and 1,800-2,000 by 1990. On the other hand, the reduced demand assumed by I-B coupled with increased frozen competition as in II-B could cut the California acreage in half over the next two decades.

As suggested by Table 10, the specific levels of the projections are less important than their comparative values. The differences could remain about the same for a range of future values of some of the exogenous variables. For example, different assumptions concerning environmental factors such as population growth and rates of inflation would affect the levels of <u>all</u> projections in roughly the same manner, so the major conclusions or inference from the experiments would not be significantly changed.

The restrictions and specific conditions pertaining to these projections should be clearly noted. They abstract from the substantial year-to-year fluctations in demand and supply response which are not accounted for by the mathematical model. The projections thus are in the form of average or expected values, with actual annual prices and production fluctuating around the projected figures. Prices in some years could fall below costs, although on the average they would not. The projections also are valid only for the type of industry behavior patterns which existed during the period used to derive the quantitative estimates of the simulation model.

If substantial changes were to occur in the ways in which growers and processors respond to price, cost, and profit experience, the model predictions would lose much of their validity, since the coefficients of the equations would be different.[1/]

Although these restrictions and conditions must be kept in view we believe that the simulation experiments provide useful insights into the future of the Brussels sprouts industry in California. Some of the situations explored in the experiments, such as the effects of different market policies, are subject to direct industry control. The results of the analysis thus may be useful in policy formation. Other situations, such as changes in the level of demand, are largely uncontrollable, but the effects need to be considered in forward planning by both growers and processors.

REVENUE EFFECTS OF SIZE VARIATION IN FROZEN BRUSSELS SPROUTS

The price data discussed in the first part of the report showed that prices of frozen Brussels sprouts decreased with increased sprout size, apparently reflecting some buyer preference for the small sizes. The allocation of individual sprouts among size categories is determined mainly by natural growth processes. However, the distribution may be altered somewhat by changes in harvesting and cultural practices and the development of new varieties. Changes in size distribution, planned, or otherwise, may affect the differences in prices among size classes. This, in turn, may alter the revenue received from a given quantity of sprouts.

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1/ Although a change in any of the model coefficients would affect the values of the experimental projections, some changes seem likely to affect mainly the general level without greatly altering the long-run comparative values of the projections. For example, a drop in the freezer inventory carryover coefficient (λ) because of high interest rates would lead to an immediate reduction of freezer raw product demand. As soon as inventory levels were adjusted to the new lower value, the basic demand values would, with other things constant, return to approximately the previous level. This type of change would affect all of the experimental projections so the comparative values probably would remain roughly the same.

To analyze the potential revenue effects of size variation we first explore the nature of demand among individual sprout size categories. From this analysis we develop an equation which expresses gross revenue as a function of quantities in each size class. This is used to evaluate the gross effects of changes in size distribution. Crude estimates of marginal costs of shifting the size distribution are then subtracted to obtain an indication of potential effects on net revenue to the industry.

Estimation of Demand by Size and Container Class

Prediction of changes in gross revenue associated with changes in sprout size distribution requires a set of equations which relate prices in each size and container class to quantities in all size-container classes. Estimation of the parameters of such equations requires continuous series of data pertaining to prices and quantities in each class, data which for the most part have never been published in any form. As indicated in the first section of the report, we were able to develop list price series by size groups for institutional size containers, but similar data are not available for retail containers and no information is published pertaining to quantities packed by size group. Therefore, it was necessary to acquire data directly from the records of processing firms in the industry.

Monthly sales and price data by size class were compiled from records of freezers covering the years 1961 and 1962.[1/] These firms sold over 65 percent of all sprouts marketed during these two years and the data are believed to be representative of total industry experience. Data covering additional periods would have been desirable but lack of complete historical records in the firms surveyed plus the sheer physical difficulties

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1/ This phase of the analysis was initiated in the early 1960's at the request of the members of the Brussels Sprouts Marketing Program. The survey of processors was completed in 1963 and preliminary analysis finished shortly thereafter. However, because of diverting assignments, the final phases were not completed until much later. A very limited amount of data has been obtained for more recent years and serves as a basis for checking the previous results.

involved in the compilations required that the survey be limited to a two-year period. The 24 monthly observations on prices and sales for three sprout size classes and two container classes are summarized in Appendix Table A-17.

The basic model to be estimated expresses the average monthly price in each size and container category as a linear function of the monthly quantity sold in each category.1/ In view of the relatively short period involved, the annual values of competing products and income included in the previous demand analysis were omitted. Quantities were expressed in total rather than per capita terms. Monthly carlot unloads of fresh Brussels sprouts in 41 U.S. cities were included as a variable to allow for both seasonal shifts and the competitive effects of the fresh commodity.2/ Initial regression estimates suggested the presence of a trend in some equations, possibly due to the omission of income and other competing products. Thus, a time trend also was added. Since there are six size-container classes, we have six equations each of the form:

$$(22) \quad P_{it} = b_{i0} + b_{i1} Q_{RLt} + b_{i2} Q_{RMt} + b_{i3} Q_{RSt} + b_{i4} Q_{ILt} + b_{i5} Q_{IMt} + b_{i6} Q_{ISt} + b_{i7} Q_{Ft} + b_{i8} T + v_{it}$$

where

Q is quantity in 1,000 pounds;

R refers to retail size containers;

I refers to institutional size containers;

L, M, S are large, medium, and small;

P is average price (cents per pound);

Q_F is monthly carlot unloads of fresh Brussels sprouts in 41 U.S. cities;

1/ Nonlinear forms are of course, equally possible. With many variables and cross-relationships, it is difficult to determine the nature of existing curvilinearity and to estimate any except the simple log form. Preliminary graphic explorations suggested that linear estimates would provide reasonable approximations within the range of the data.

2/ See Appendix Table A-8 for data on carlot unloads.

T is a time trend, varying from 1 to 24;

i = 1, 2, . . . 6, indicated a particular size-container category (e.g., $P_{1t} = P_{RLt}$);

t = 1, 2, . . . 24, indicates the number of the monthly observation; and

v is an unexplained disturbance.

The choice of statistical procedure to use in estimating the parameters of this equation system involved both theoretical and empirical considerations. Since we are dealing with monthly observations our initial approach was to view the demand equations as part of a simultaneous system. That is, monthly quantities sold were regarded as determined simultaneously with monthly prices. This view required that we specify short-run supply equations and then estimate the parameters of the entire demand-supply system by simultaneous equations procedures.

Supply equations were formulated in which the monthly quantities of sprouts marketed, by size class, were expressed as linear functions of prices, and beginning monthly inventory levels in each size class. The latter were adjusted for normal seasonal variation. Beginning inventories were viewed as predetermined variables, thus producing a system in which the coefficients of the demand equations were identified.

The parameters of this system of equations were estimated by two-stage least squares. The results were quite unsatisfactory, both by usual statistical criteria and in terms of the expected signs and magnitudes of the equation coefficients. This may have been due in substantial part to the very poor quality of our data pertaining to monthly quantities of each size category held in cold storage.[1/] In any case, it was necessary to abandon this procedure and turn to other methods of estimation.

Our second approach was to apply ordinary least squares directly to the estimation of the parameters of each structural equation. This method

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1/ Published data on monthly cold storage holdings do not indicate the quantities held in each size category. These values were estimated on the basis of total stocks and the proportions packed initially in each size class. Such estimates could be very inaccurate.

is justified if processors establish quantities to be sold each month without regard to current price. We would not argue that processor plans and adjustments are so completely inflexible, but they may well be more concerned with orderly movement of total stocks and honoring buyer commitments than with adjustments to monthly price variations. Under these circumstances the degree of bias may be "reasonably" small.

The results of our initial application of ordinary least squares, although superior to the two-stage least squares model, still had some coefficients with positive signs or of low statistical significance. The main difficulty appeared to be that the sample was too small, the range of observations too limited, and the intercorrelation among quantity variables too high to isolate the separate effects on price of each of the six alternative size-container classes in each equation. To reduce the intercorrelation problem and the number of coefficients to be estimated we combined several of the variables in each equation. Three variations were considered.

First, we related the price in each size-container class to the three sizes in the corresponding container type and the total quantity in the other container type. For example, P_{RM} was related to Q_{RL}, Q_{RM}, Q_{RS}, and Q_I, where $Q_I = Q_{IL} + Q_{IM} + Q_{IS}$.

A second formulation related the price in each size-container class to the quantity in that class, to all other quantities in the same container type, and to total quantities in the alternate container type.

The third formulation related price in each size-container class to the quantity in that class and the total quantity in all other classes.

In nearly all cases the third formulation provided the most satisfactory results measured by both theoretical and statistical criteria. These regressions are summarized in Table 11. All of the coefficients are consistent with theoretical expectations--i.e., they are all negative and each price is affected more by changes in its own quantity than by quantities in other classes. Sales of fresh Brussels sprouts (Q_F) had a highly significant effect on prices of medium sprouts and a somewhat significant effect on prices of small sprouts in retail size containers.

TABLE 11

Demand Relationships for Frozen Brussels Sprouts by Size-Container Class: Final Selected Regressions

Dependent variable	Constant term	Explanatory variables[a/]									R[c/]	d[d/]
		Q_{RL}	Q_{RM}	Q_{RS}	Q_{IL}	Q_{IM}	Q_{IS}	$Q_T - Q_i$[b/]	Q_F	T		
	regression coefficients and t-ratios[e/]											
P_{RL}	25.197	-.00136 (1.721)						-.00045 (2.421)		-.03450 (3.689)	.773	1.68
P_{RM}	27.887		-.00051 (1.710)					-.00027 (1.403)	-.00252 (2.294)	-.01249 (1.795)	.801	1.20
P_{RS}	29.914			-.00235 (2.756)				-.00024 (1.116)	-.00182 (1.487)	-.01628 (1.959)	.773	1.75
P_{IL}	22.827				-.00334 (4.152)						.663	2.76
P_{IM}	26.234					-.00132 (3.049)		-.00027 (1.942)	-.00406 (4.865)		.945	2.39
P_{IS}	27.064						-.00636 (3.906)	-.00013 (1.458)			.732	1.85

a/ See text for explanation of symbols.

b/ $Q_T = Q_{RL} + Q_{RM} + Q_{RS} + Q_{IL} + Q_{IM} + Q_{IS}$. Q_i refers to the variable treated as dependent.

c/ Coefficient of multiple correlation.

d/ Durbin-Watson statistic. The hypothesis of no positive serial correlation of error terms is not rejected at the 5 percent significance level for the first, fourth, fifth, and sixth equations. The value of d falls in the indeterminant range for the second and third equations. There is a suggestion of negative serial correlation for the fourth equation.

e/ Figures in parentheses are t-ratios.

The coefficient of Q_F was of quite low statistical significance in the equations for large size sprouts and for small institutional sprouts. Therefore, Q_F was omitted in the final regressions for these classes. The trend factor was not significant for institutional size containers and so was omitted from the latter set of equations. In the case of large sprouts in institutional containers, the coefficient of $Q_T - Q_{IL}$ was positive and of very low statistical significance. Similar results were obtained for other variations, so all competing product variables were dropped from this equation--i.e., their coefficients are regarded as zero.

Why sales of fresh sprouts should influence prices of medium frozen sprouts and not the large sprouts or institutional small is not clear. Possibly the extreme size classes are less sensitive to the fresh market. It is also possible that a significant relation may exist, but did not show up in our relatively small sample of observations.

Since our focus is on demand interrelationships among the frozen components only, we shall hold sales of fresh sprouts constant at the mean value for the period of the study and arbitrarily set T at zero. The resulting set of equations, summarized in Table 12, form the basis for our further analysis. If fresh sales had been set at (say) a lower level, the demand for medium sizes would have been shifted upward relative to large sizes. Similarly, if T had been set at (say) 12 or 24, rather than zero, the demands for retail containers would have been reduced relative to the institutional containers and the demand for the retail large class would have been reduced relative to the medium and small. These small shifts would slightly alter the solutions to the problem of optimum distribution in favor of the medium class, but the major conclusions would remain essentially the same.

The constant term in each equation measures the level of demand for the size-container class of the dependent variable.[1/] As expected, the level is

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1/ These equations reflect 1961-1962 levels of demand. Our previous analysis of annual demand data indicates that the 1968-1969 level of demand was about one-third higher as a result of the net effects of changes in population, income, and competing products. Thus, the constant terms in Table 12 would be increased by about one-third to adjust to these more recent levels. This would not alter the major conclusions of the analysis.

TABLE 12

Final Demand Model for Frozen Brussels Sprouts by Size-Container Class (Q_f = 58.6 and T = 0)

Dependent variable	Constant term	Explanatory variables					
		Q_{RL}	Q_{RM}	Q_{RS}	Q_{IL}	Q_{IM}	Q_{IS}
		equation coefficients					
P_{RL}	25.197	-.00136	-.00045	-.00045	-.00045	-.00045	-.00045
P_{RM}	27.379	-.00027	-.00051	-.00027	-.00027	-.00027	-.00027
P_{RS}	29.807	-.00024	-.00024	-.00235	-.00024	-.00024	-.00024
P_{IL}	22.827				-.00334		
P_{IM}	25.996	-.00027	-.00027	-.00027	-.00027	-.00132	-.00027
P_{IS}	27.064	-.00013	-.00013	-.00013	-.00013	-.00013	-.00636

higher for retail sizes and decreases with increased sprout size. The equation coefficients show the effect of a 1,000-pound change in monthly sales of a particular product with all other quantities constant.[1/] For example, the first equation indicates that increasing monthly sales of large size sprouts in retail containers by 1,000 pounds decreases the average price of this commodity by 0.00136 cents per pound, with other quantities constant. Increasing one of the other quantities by 1,000 pounds, with Q_{RL} constant, would decrease P_{RL} by 0.00045 cents. These equations are generally more flexible--a given percentage change in quantity has a smaller percentage effect on price--than our estimates of annual demand relationships. This is to be expected with the interrelated demands.

Two other factors may also have influenced the levels of the coefficients. In view of the simultaneous equation considerations discussed earlier, it is possible that the method of estimation may have produced biased estimates of the true demand structure. It is also possible that the relatively narrow range of price variation and limited sample may have prevented our capturing the full effects of changes in general levels of sales on prices that would be observed over longer periods and with more shift variables. However, the relative magnitudes of the equation coefficients may be less affected by these considerations and the equation may provide an acceptable basis for evaluating the potential revenue effects of changes in distribution, with total quantity held constant.

Revenue Effects

The set of equations in Table 12 may be readily converted to a single equation which shows how monthly gross revenue changes with quantities allocated to each size-container class. We simply multiply each equation by the quantity corresponding to the dependent price variable and then sum.

$$(23)\quad GR = P_{RL}\,Q_{RL} + P_{RM}\,Q_{RM} + P_{RS}\,Q_{RS} + P_{IL}\,Q_{IL} + P_{IM}\,Q_{IM} + P_{IS}\,Q_{IS}.$$

Replacing each price with its demand equation expresses gross revenue as a function only of quantities in each class. The first term of (23), for

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1/ The 1,000-pound change for our 65 percent sample would be translated into a $\frac{1,000}{.65}$ = 1,538-pound change for the entire industry.

example, would be,

$$25.197\ Q_{RL} - .00136\ Q_{RL}^{\ 2} - .00045\ Q_{RL}\ (Q_{RM} + Q_{RS} + Q_{IL} + Q_{IM} + Q_{IS}),$$

and similarly for other terms.[1/]

Equation (23) may be used in two ways. First, it may be used to show how small changes in the present (sample) allocation of sizes may affect revenue. The expected revenue changes may then be compared with expected cost effects. Second, Equation (23) may be combined directly with estimates of cost relationships to determine allocations among size-container classes that will maximize expected industry net revenue for any total quantity of Brussels sprouts produced. The first procedure enables us to extract useful information from the revenue function without immediate reference to or knowledge of costs. This has considerable merit in view of the somewhat uncertain nature of our current estimates of cost-size-of-sprout relationships. With changes in varieties and harvesting methods our estimates of costs, to be discussed shortly, must be regarded as highly tentative at best.

Marginal Revenue Effects

Table 13 shows how small shifts in allocation from one size-container class to another may affect gross revenue, starting with the initial average allocation in our sample.[2/] For example, shifting 1,000 pounds from the retail large class to the retail medium class would increase average monthly gross revenue by approximately \$25.58. Shifting the same 1,000 pounds to the retail small class would increase gross revenue by \$45.25. Shifting quantities from retail to institutional containers would, in general, decrease gross revenue. However, costs of packaging in the larger

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1/ Since prices are expressed in cents per pound and quantities in 1,000-pound units, Equation (23) must be multiplied by 1,000 to obtain the true gross revenue in cents or by 10 to obtain GR in dollars.

2/ Values in Table 13 were computed by first calculating marginal revenues for each commodity with quantities at average levels observed over the sample; $MR_i = \frac{\partial GR}{\partial Q_i}$. Taking the total differential of the gross revenue equation, we have $dGR = \sum_{i=1}^{6} MR_i dQ_i$. For any pair of classes (i and j) we set $dQ_i = 1$, $dQ_j = -1$, all other $dQ = 0$, and compute dGR.

TABLE 13

Changes in Gross Revenue Associated with Shifting 1,000 Pounds of Frozen Brussels Sprouts from One Size-Container Class to Another[a]

1,000 pound decrease in	1,000 pound increase in				
	Q_{RM}	Q_{RS}	Q_{IL}	Q_{IM}	Q_{IS}
	dollars				
Q_{RL}	25.58	45.25	-24.42	10.19	24.20
Q_{RM}		19.67	-50.00	-15.39	- 1.38
Q_{RS}			-69.67	-35.06	-21.05
Q_{IL}				34.61	48.62
Q_{IM}					14.01

a/ Starting with average sample quantities in each class.

containers are somewhat lower and this needs to be considered in any final evaluation. Shifting between sizes within container categories may also involve some cost difference, although generally less than between container types. These actual or potential transfer costs must be subtracted from gross revenue changes to determine the potential marginal net gains.

To obtain information on costs of altering the size distribution we made detailed studies of both production and processing operations that might be affected by size variations. In the case of processing, the main cost influence was in the trimming operation and, in production, the time intervals between harvests. The study indicated that with conventional multiple harvest cultural practices, shifting one pound of sprouts from the large to the medium size would increase the combined production and processing cost by about 0.9 cents per pound.[1/] Shifting a pound from the medium to small class would increase costs by another 0.9 cents per pound. Since our focus is primarily on size distribution we have assumed that the average observed price difference between container types for the same sprout size reflects the difference in cost of packaging in retail and institutional size containers. This was 1.73 cents per pound (for all sprout sizes) during the period for which data were obtained.

By subtracting these estimates of transfer costs from the gross marginal changes in Table 13 we obtain the marginal net revenue estimates shown in Table 14. Thus, shifting 1,000 pounds from retail large to retail medium increases total net revenue by $16.58; shifting the same 1,000 pounds to retail small increases net revenue by $27.25, and similarly for other shifts. The potential gains from size shifts appear to be somewhat larger for institutional than retail size packages. In general, the table suggests that net revenue could be increased by a program aimed at shifting quantities from large into medium and small categories. However, it does not indicate how much should be shifted or what the final distribution should be. For this purpose, we need to make additional calculations.

1/ For details of the cost estimates see Matsumoto, Masao, "An Economic Analysis of Product Size Variation in the Frozen Brussels Sprouts Industry," unpublished doctoral dissertation, Berkeley: University of California, 1968.

TABLE 14

Changes in Net Revenue Associated with Shifting 1,000 pounds of Frozen Brussels Sprouts from One Size-Container Class to Another[a]

1,000 pound decrease in	1,000 pound increase in				
	Q_{RM}	Q_{RS}	Q_{IL}	Q_{IM}	Q_{IS}
	dollars				
Q_{RL}	16.58	27.25	- 7.12	18.49	23.50
Q_{RM}		10.67	-23.70	2.21	6.92
Q_{RS}			-34.37	- 8.76	- 3.75
Q_{IL}				25.61	30.62
Q_{IM}					5.01

a/ Starting with average sample quantities in each class.

<u>Estimates of Optimal Size Distribution</u>

We shall define as "optimal" the distribution of sprout sizes that maximizes the expected value of net revenue to the industry. The manner in which any revenue gains might be divided between growers and processors would depend on the size class structure of processor-grower payments. This analysis is limited to the potential for industry gain and not to its distribution. Presumably, if the possible gain is significant, appropriate plans can be devised for its distribution.

The mathematical problem to be solved is to find, for any given total quantity of sprouts, the allocation to each size-container class that will maximize gross revenue less the costs of production and processing. With total quantity constant, only the cost differences associated with each size-container class need be considered. These costs were described in the previous section. The solution procedure is described in Appendix C.

Table 15 shows the optimal distribution for the total quantity of average monthly sales observed during the period covered by the data, compared to the actual size distribution observed during the same period. Three alternative solutions are presented, each involving different restrictions on the quantity of large sprouts. Solution 1 imposes only the restriction that the quantity in each class must be greater than or equal to zero. Because it may be unreasonable to assume that the quantity in large sizes can be reduced to zero (without abandoning parts of the production), we have computed two additional solutions which require that at least (a) five percent and (b) ten percent of the production will fall in the large class. To focus entirely on the size allocation problem, solutions 2 and 3 also restrict the distribution between retail and institutional containers to the proportions observed during the sample period.

The three solutions give similar results. They leave the proportions allocated to medium sizes with little change, reduce the quantity in large sizes and increase the allocation to smaller sprouts. Solution 1 increases industry revenue, compared with the value observed during the sample period, by $133,540 per year, solution 2 by $123,130, and solution 3 by $88,430. These values were obtained by expanding sample values to reflect total industry experience.

The optimal allocation proportions in Table 15 pertain only to the quantities sold during the sample period, 1961-1962. As the sales change, so do the optimal allocations among size classes. Figure 23 shows the nature of this change for each of the three solutions with quantities in large sizes restricted to minimum levels of zero, five percent, and ten percent.[1/] As industry sales increase, the allocation to medium sizes increases and the optimal allocation to small sizes decreases. With sales of 40 million pounds per year (roughly the recent industry experience), solution 3, for example, would allocate 63 percent to medium, 27 percent to small, and 10 percent to large sizes. The expected or potential gain from this allocation is difficult to compute because of incomplete data pertaining to recent size distribution. Using the sample values given in Table 2 for 1964-1968 and the allocations between retail and institutional size containers observed in the 1961-1962 sample suggests a potential current gain of roughly $187,000 per year. In view of the very rough nature of our estimates of current size distributions, this may substantially overestimate the magnitude of the potential gain. It suggests, however, that the possibility for some real increase in net revenue may still remain.

Evaluation of Size of Sprout Analysis

In view of the statistical problems and data limitations noted above, the computations and estimates pertaining to optimum size allocations should not be interpreted as precise values. Our sample period of observations is shorter and less current than we would wish and the cost estimates used to obtain net values are rough and somewhat uncertain with the shift toward mechanical harvesting. The figures are suggestive, however, of general directions of change which could lead to modest increases in industry revenue.

The major inference from the analysis is that efforts aimed at reducing the proportion of large sizes and increasing the proportion in small sizes could produce some industry gain, provided the costs of change do not greatly

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1/ In this case, restricting the quantity in large sizes to a minimum level forces the large quantity to equal that level (see Appendix C).

TABLE 15

Actual and Optimal Distribution of Sprout Sizes for the 1961-1962 Sample Quantity of Sales

Size-container class	Actual distribution	Optimal distributions		
		Solution 1[a]	Solution 2[b]	Solution 3[c]
	proportion of total			
Large				
Retail	.096	.000	.023	.046
Institutional	.114	.000	.027	.054
TOTAL	.210	.000	.050	.100
Medium				
Retail	.488	.473	.483	.449
Institutional	.154	.204	.153	.142
TOTAL	.642	.677	.636	.591
Small				
Retail	.126	.270	.267	.263
Institutional	.022	.053	.047	.046
TOTAL	.148	.323	.314	.309

a/ $\frac{Q_L}{Q_T} \geq 0.$

b/ $\frac{Q_L}{Q_T} \geq .05$ and $Q_{RL} = .457Q_L$, $Q_{RM} = .759Q_M$, $Q_{RS} = .852Q_S$.

c/ Restrictions same as for solution (2) except $\frac{Q_L}{Q_T} \geq .10.$

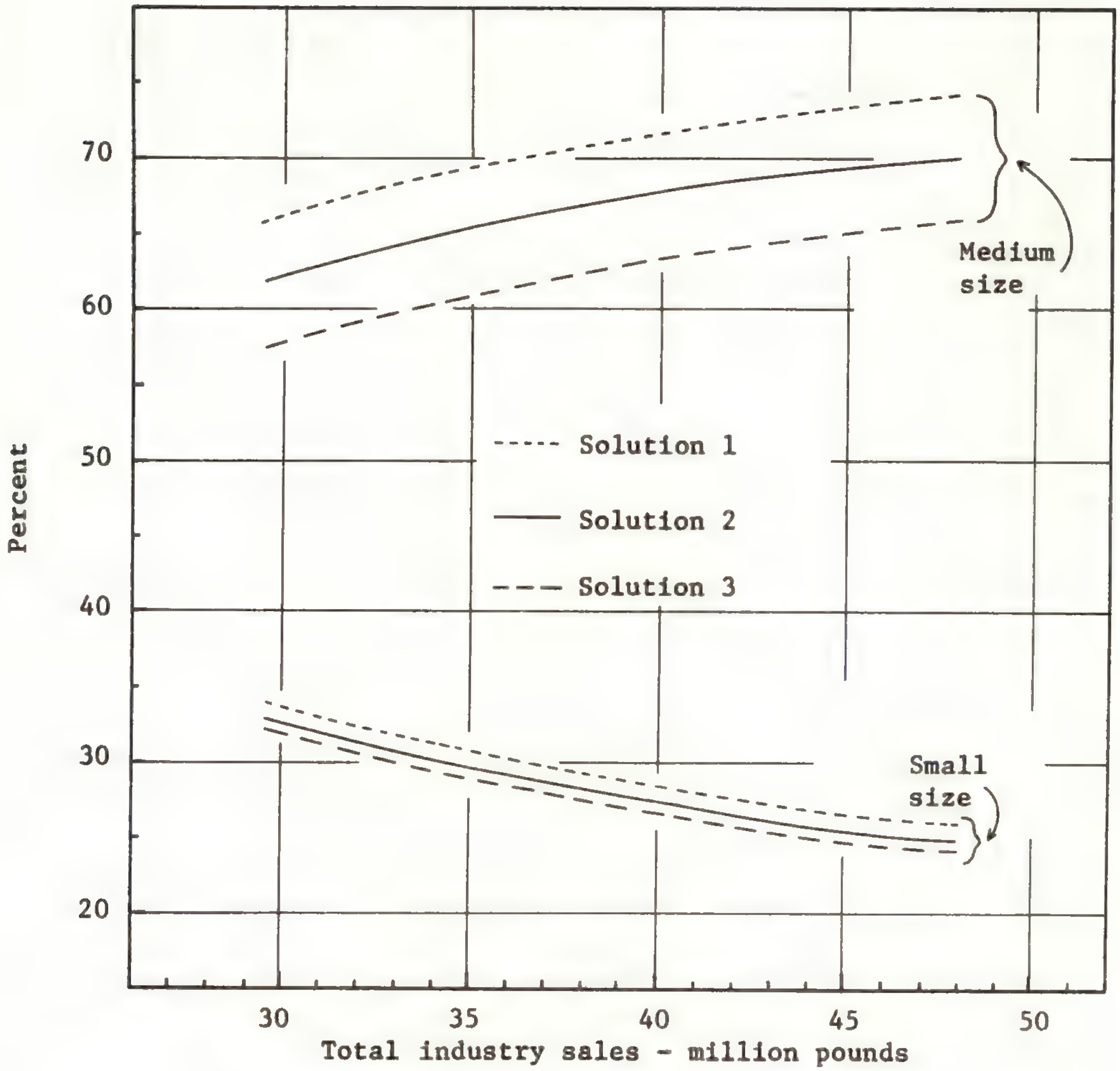

FIGURE 23

Relation of Expected Optimal Brussels Sprouts Size Distribution to Total Quantity of Industry Sales

exceed the values used in our study. This is "imperfect" information. Moreover, the potential gain is not large in a relative sense--in the neighborhood of perhaps one percent of f.o.b. sales value. Whether potential gains of this size are worth striving for depends on the industry attitude and willingness to apply imperfect information in making marketing policy decisions. In this case, the probability of gain appears to be larger than the probability of loss and the magnitude of the gain could be considered significant in periods of tight margins and higher costs.

APPENDIX A

Reference Data

(Tables A-1 to A-22)

TABLE A-1

Acreage of California Brussels Sprouts, by Counties, 1949-1967

Year	County					
	Monterey	San Luis Obispo	San Mateo	Santa Cruz	Other counties	Total
	acres					
1949	500	70	2,060	1,770	--	4,400
1950	800	100	2,200	2,400	--	5,500
1951	500	100	1,900	2,200	--	4,700
1952	230	--	1,610	2,220	40	4,100
1953	300	--	2,280	2,600	20	5,200
1954	200	--	2,770	2,400	30	5,400
1955	160	--	1,850	1,960	30	4,000
1956	160	--	2,700	2,640	100	5,600
1957	120	--	2,500	2,620	60	5,300
1958	130	--	1,800	2,300	70	4,300
1959	120	--	1,900	2,730	50	4,800
1960	120	60	1,960	2,560	--	4,700
1961	150	70	1,810	2,820	50	4,900
1962	230	80	2,250	2,720	20	5,300
1963	390	150	1,500	3,340	20	5,400
1964	600	120	1,530	3,000	50	5,300
1965	750	130	1,320	2,950	50	5,200
1966	840	170	1,470	3,200	20	5,700
1967	500	250	1,250	3,600	100	5,700

Source: California Federal-State Market News Service, *Marketing California Brussels Sprouts*, annual issues (compiled from reports of the California Crop and Livestock Reporting Service.)

TABLE A-2

Brussels Sprouts: Acreage, Yield, and Production in Major Producing States, 1949-1968 a/

Year	Harvested acreage			Yield per acre		Production		
	California	Other	U.S.	California	Other (NY)	California	Other	U.S.
	acres			cwt.		1,000 cwt.		
1949	4,400	600	5,000	94	75	414	45	459
1950	5,500	900	6,400	68	80	374	72	446
1951	4,700	900	5,600	100	60	470	54	524
1952	4,100	700	4,800	94	55	385	38	423
1953	5,200	700	5,900	122	60	634	42	676
1954	5,400	1,050	6,450	108	60	583	50	633
1955	4,000	1,000	5,000	104	55	416	51	467
1956	5,600	800	6,400	125	75	700	55	755
1957	5,300	1,200	6,500	105	80	556	64	622
1958	4,300	750	5,050	120	85	516	56	573
1959	4,800	760	5,560	130	85	624	62	686
1960	4,700	810	5,510	140	75	658	58	716
1961	4,900	800	5,700	135	55	662	44	706
1962	5,300	700	6,000	115	75	610	49	659
1963	5,400	800	6,200	115	75	621	60	681
1964	5,300	900	6,200	125	75	662	68	730
1965	5,200	1,200	6,400	130	70	581	84	665
1966	5,700	1,200	6,900	115	65	656	78	734
1967	5,700	1,200	6,900	110	64	627	58	685
1968	5,600	1,300	6,900	100	65	560	78	638

a/ Data refer to "commercial" production only. Acreage and yields are not reported for minor states. However, U.S. production data given in Table A-3 include minor state quantities.

Source: U.S. Department of Agriculture, Statistical Reporting Service, *Vegetables for Fresh Market*, statistical summaries, Crop Reporting Board, Washington, D.C.

TABLE A-3

Utilization of United States and California Brussels Sprouts Production, Crop Years 1947-1968 a/

Year	United States			California			Other region production		
	Frozen	Fresh	Total b/	Frozen c/	Fresh	Total	Frozen d/	Fresh	Total
	million pounds--raw product weight								
1947	6.14	36.46	42.60	5.70	30.90	36.60 e/	.44	5.56	6.00
1948	13.43	29.77	43.20	12.94	24.26	37.20 e/	.49	5.51	6.00
1949	27.36	20.05	47.40	26.75	14.65	41.40	.61	5.39	6.00
1950	24.32	21.78	46.10	22.42	14.98	37.40	1.90	6.80	8.70
1951	26.26	27.64	53.90	24.94	22.06	47.00	1.32	5.59	6.90
1952	27.98	15.82	43.80	27.16	11.34	38.50	.82	4.48	5.30
1953	47.85	21.25	69.10	46.00	17.40	63.40	1.85	3.85	5.70
1954	35.96	28.84	64.80	33.73	24.57	58.30	2.23	4.27	6.50
1955	28.84	19.36	48.20	28.18	13.42	41.60	.66	5.94	6.60
1956	53.98	22.72	76.70	51.51	18.49	70.00	2.47	4.23	6.70
1957	35.36	27.64	63.00	32.77	22.83	55.60	2.59	4.81	7.40
1958	38.08	20.02	58.10	37.03	14.57	51.60	1.05	5.45	6.50
1959	40.87	28.23	69.10	39.07	23.33	62.40	1.80	4.90	6.70
1960	46.70	25.50	72.20	44.38	21.42	65.80	2.32	4.08	6.40
1961	49.60	22.10	71.70	47.06	19.14	66.20	2.54	2.96	5.50
1962	46.41	20.39	66.80	43.57	17.43	61.00	2.84	2.96	5.80
1963	48.30	21.00	69.30	44.40	17.70	62.10	3.90	3.30	7.20
1964	54.26	19.84	74.10	47.69	18.51	66.20	6.57	1.33	7.90
1965	51.14	16.56	67.70	44.77	13.33	58.10 f/	6.37	3.23	9.60
1966	57.82	16.68	74.50	50.02	15.58	65.60	7.80	1.10	8.90
1967	53.61	19.50	73.11 g/	45.95	16.75	62.70	7.66	2.75	10.41
1968 g/	49.12	16.88	66.00	40.91	15.09	56.00	8.21	1.79	10.00

a/ Total production of Brussels sprouts is reported on a crop year basis with no breakdown as to utilization. Utilization estimates were obtained by converting NAFFP frozen pack data to a fresh weight basis and subtracting from total production. Since U.S. frozen pack statistics are reported only for the calendar year, it was necessary to develop estimates on a crop year basis. The procedure followed is described in Appendix B.

b/ Includes production in minor states.

c/ For the period 1947-1960 raw product weight of frozen pack was estimated by applying a factor of 1.173 to the crop year pack estimate (Table A-5). The conversion factor was developed from California Brussels Sprouts Marketing Program data on packer receipts and pack, 1961-1967. From 1961 on, crop year raw product weight of California frozen Brussels sprouts was obtained directly from records of the California Brussels Sprouts Marketing Program.

d/ Frozen pack (Table A-5) multiplied by 1.173.

e/ Not officially reported for 1947 and 1948. Estimated as United States less 6.00 million pounds.

f/ Does not include 9.5 million pounds produced buy not marketed.

g/ Preliminary value.

Source: Computed from data in Table A-5. Estimates of total U.S. Brussels sprouts production are from U.S. Department of Agriculture, Statistical Reporting Service, *Vegetables for Fresh Market*, Statistical Bulletins 126, 212, 300, 412, Washington, D.C., 1953-1967. Data pertaining to frozen to fresh conversion factors obtained from California Federal-State Market News Service, *Marketing California Brussels Sprouts*, annual issues.

TABLE A-4

Relative Utilization of Brussels Sprouts Production, by Regions, Crop Years 1947-1968

Year	California's share of U.S. production			Percent of production utilized for freezing		
	Frozen	Fresh	Total	California	Other	U.S.
	percent					
1947	92.8	84.8	85.9	15.6	7.3	14.4
1948	96.3	81.5	86.1	34.8	8.2	31.1
1949	97.8	73.1	87.3	64.6	10.2	57.7
1950	92.2	68.8	81.1	60.0	21.8	52.8
1951	95.0	79.8	87.2	53.1	19.1	48.7
1952	97.1	71.7	87.9	70.5	15.5	63.9
1953	96.1	81.9	91.8	72.6	32.4	69.2
1954	93.8	85.2	90.0	57.8	34.3	55.5
1955	97.7	69.3	86.3	67.7	10.0	59.8
1956	95.4	81.4	91.3	73.6	36.9	70.4
1957	92.7	82.6	88.3	58.9	35.0	56.1
1958	97.2	72.8	88.8	71.8	16.2	65.5
1959	95.6	82.3	90.3	62.6	26.9	59.1
1960	95.0	84.0	91.1	67.4	36.2	64.7
1961	94.9	86.7	92.3	71.1	46.2	69.2
1962	93.9	85.6	91.3	71.4	48.9	69.5
1963	91.9	84.3	89.6	71.5	54.2	69.7
1964	87.9	93.3	89.3	72.0	83.2	73.2
1965	87.5	80.5	85.8	77.1	66.3	75.5
1966	86.5	93.4	88.1	76.3	87.6	77.6
1967	85.7	85.9	85.8	73.3	73.6	73.3
1968a/	83.3	89.4	84.8	73.1	82.1	74.4

a/ Preliminary value.

Source: Computed from Table A-3.

TABLE A-5

United States and Regional Packs of Frozen Brussels Sprouts, 1947-1968

Year	Estimated crop year pack (August 1 - July 31)			Calendar year pack		
	California	Other	U.S.	California	Other	U.S.
	million pounds--frozen weight					
1947	4.858	0.379	5.237	4.178	0.379	4.557
1948	11.035	0.418	11.453	10.108	0.418	10.526
1949	22.803	0.516	23.319	22.939	0.516	23.455
1950	19.109	1.620	20.729	20.819	1.620	22.439
1951	21.264	1.119	22.383	21.357	1.119	22.476
1952	23.151	0.700	23.851	21.754	0.700	22.454
1953	39.219	1.573	40.792	39.228	1.573	40.801
1954	28.760	1.899	30.659	31.519	1.899	33.418
1955	24.026	0.559	24.585	22.583	0.559	23.142
1956	43.911	2.108	46.019	41.881	2.108	43.989
1957	27.936	2.207	30.143	31.147	2.207	33.354
1958	31.569	0.896	32.465	29.528	0.896	30.424
1959	33.312	1.533	34.845	37.200	1.533	38.733
1960	37.839	1.975	39.814	37.286	1.975	39.261
1961	40.002	2.163	42.165	37.894	2.163	40.057
1962	37.904	2.424	40.328	37.910	2.424	40.334
1963	38.279	3.326	41.605	38.946	3.326	42.272
1964	41.502	5.605	47.107	41.871	5.605	47.476
1965	36.997	5.428	42.425	31.911	5.428	37.339
1966	42.172	6.648	48.820	45.050	6.648	51.698
1967	39.021	6.539	45.555	32.940	6.539	39.479
1968	36.415	7.000	43.415	42.016	7.000	49.024

Source: Calendar year disappearance (D_t) was computed from National Association of Frozen Food Packers calendar year pack data and USDA, Economic Research Service, *Cold Storage Reports*, January 1 stock data. See Appendix B for method of estimating seasonal (crop year) pack.

TABLE A-6

United States Production of Frozen Brussels Sprouts by Major Package Type, Calendar Years 1947-1968

Year	U.S. pack: Retail size packages a/	U.S. pack: Institutional size packages b/	Total	Percent of pack in retail sizes
	million pounds			
1947	3.511	1.046	4.557	77.0
1948	8.012	2.514	10.526	76.1
1949	17.237	6.218	23.455	73.5
1950	17.485	4.954	22.439	77.9
1951	15.940	6.536	22.476	70.1
1952	16.690	5.764	22.454	74.3
1953	31.490	9.311	40.801	77.2
1954	21.674	11.744	33.418	64.9
1955	17.999	5.143	23.142	77.8
1956	32.183	11.806	43.989	73.2
1957	24.441	8.913	33.354	73.3
1958	23.506	6.918	30.424	77.3
1959	27.364	11.369	38.733	70.6
1960	28.139	11.122	39.261	71.7
1961	28.952	11.105	40.057	72.3
1962	28.318	12.016	40.334	70.2
1963	24.363	17.909	42.272	57.6
1964	28.254	19.222	47.476	59.5
1965	23.565	13.774	37.339	63.1
1966	32.018	19.680	51.698	61.9
1967	27.511	11.968	39.479	69.7
1968	32.153	16.863	49.016	65.6

a/ Includes all containers of one pound and under (including boil-in-bag and poly bag).

b/ Includes all containers over one pound.

Source: Annual reports of the National Association of Frozen Food Packers, Washington, D.C.

TABLE A-7

Total United States Shipments of Fresh Brussels Sprouts, by Months, 1963-1969 a/

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
	cars and carlot equivalents												
1963-1964	2	20	78	125	147	169	177	99	36	5	--	--	858
1964-1965	3	32	133	184	197	171	92	27	17	10	9	12	887
1965-1966	--	19	84	140	127	73	103	64	42	14	2	2	670
1966-1967	1	19	77	91	115	136	103	75	26	2	--	--	645
1967-1968	--	9	45	82	128	135	169	109	16	11	1	1	706
1968-1969	--	17	67	127	132	140	102	51	16	9	10	4	675

a/ Includes only shipments originating in the United States. Difference between U.S. shipments and unloads (Table A-8) apparently is due to exports to Canada and imports from Mexico. Data for earlier years not available on a comparable basis.

Source: California Federal-State Market News Service, *Marketing California Brussels Sprouts*.

TABLE A-8

Total Rail and Truck Unloads of Fresh Brussels Sprouts in 41 United States Cities and Canada, by Months, 1960-1969

Year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
	cars and carlot equivalents												
United States cities only													
1960-1961	--	32	98	159	189	142	40	20	5	1	--	--	686
1961-1962	2	38	72	153	152	124	91	74	12	2	--	--	720
1962-1963	--	17	94	165	151	76	59	40	26	24	9	1	662
1963-1964	2	10	62	118	120	124	145	119	60	12	3	8	783
1964-1965	5	17	89	160	181	144	93	34	21	11	9	12	776
1965-1966	5	5	74	119	118	61	65	67	64	30	20	10	638
1966-1967	1	20	58	78	108	80	97	82	46	12	12	5	599
1967-1968	--	6	31	70	103	85	134	118	49	54	32	14	696
1968-1969	2	11	49	91	117	108	92	79	53	57	31	6	696
Five Canadian cities													
1965-1966	4	6	34	35	17	6	17	13	7	10	11	2	162
1966-1967	--	6	19	42	46	42	19	16	10	3	4	4	211
1967-1968	--	10	19	26	24	28	19	29	12	12	6	6	191
1968-1969	--	13	23	30	13	30	32	13	11	7	9		181

Source: California Federal-State Market News Service, *Marketing California Brussels Sprouts*, 1960-1969 issues.

TABLE A-9

California Frozen Brussels Sprouts Pack, by Months, 1959-1969

Year	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Crop year total a/
	million pounds							
1959-1960	--	10.038	13.115	4.831	5.328	--	--	33.313
1960-1961	--	9.672	14.451	8.135	4.765	0.817	--	37.840
1961-1962	--	12.681	10.920	6.861	6.681	2.810	0.048	40.001
1962-1963	--	10.329	12.984	6.739	4.943	2.908	--	37.903
1963-1964	--	6.629	11.234	12.964	5.029	2.423	--	38.279
1964-1965	2.894	14.879	15.312	6.737	1.680	--	--	41.502
1965-1966	--	4.794	14.365	7.823	4.893	3.874	1.272	37.021
1966-1967	3.297	9.579	10.944	8.630	8.272	1.451	--	42.173
1967-1968	--	7.966	7.769	7.712	7.824	6.385	1.365	39.021
1968-1969	2.722	6.458	8.007	12.720	4.818	1.283	0.407	36.415

a/ Totals do not coincide exactly with NAFFP data which are calendar year. They may also deviate slightly from our crop year estimates (Table A-5) because of formula adjustments applied to the NAFFP data.

Source: Computed from weekly pack data reported in California Federal-State Market News Service, *Marketing California Brussels Sprouts*, annual issues.

TABLE A-10

United States End-of-Month Cold Storage Holdings of Frozen
Brussels Sprouts, 1959-1968

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	million pounds											
1959	25.040	21.034	18.289	16.138	14.523	11.796	9.737	8.394	14.161	21.460	27.256	26.712
1960	23.790	19.998	17.037	14.199	11.671	9.414	7.185	6.392	15.122	20.422	26.600	28.161
1961	26.365	23.027	18.988	17.441	14.321	11.729	10.549	10.538	15.439	22.495	29.283	30.986
1962	29.644	27.328	24.775	21.030	17.818	14.342	13.606	11.301	15.751	25.914	29.824	30.872
1963	28.925	25.732	22.901	19.989	16.113	14.106	11.779	9.920	11.208	21.131	29.840	32.353
1964	30.317	26.982	22.939	20.075	17.232	14.680	13.674	10.903	16.364	28.147	35.090	35.336
1965	30.632	28.387	25.524	20.833	17.560	14.609	13.185	10.217	12.273	20.233	27.891	28.458
1966	27.794	24.935	21.756	19.366	16.646	14.502	12.350	12.375	17.989	26.193	33.489	37.681
1967	35.433	35.951	33.252	30.105	27.070	23.393	20.716	17.345	19.783	28.993	35.290	35.359
1968	35.887	33.661	31.566	29.423	24.812	21.873	18.653	17.387	21.744	31.503	40.916	45.389

Source: U.S. Department of Agriculture, Statistical Reporting Service, *Regional Cold Storage Holdings*, summaries, Crop Reporting Board, Washington, D.C.

TABLE A-11

Quarterly Movement of California Frozen Brussels Sprouts, 1959-1967 a/

Year	Sept.-Nov.	Dec.-Feb.	Mar.-May	June-Aug.	Total
	million pounds				
1959-1960	9.876	12.496	7.920	5.015	35.307
1960-1961	13.060	6.230	11.074	3.579	33.943
1961-1962	12.729	11.498	8.958	6.139	39.324
1962-1963	12.604	12.246	8.859	5.704	39.413
1963-1964	12.480	11.137	8.599	8.477	40.693
1964-1965	15.595	8.387	9.246	6.271	39.499
1965-1966	11.888	12.140	7.219	7.017	38.264
1966-1967	10.763	8.873	7.416	8.120	35.172

a/ Computed by adding quarterly pack to stocks at the beginning of each quarter and subtracting ending stocks. California cold storage stocks were estimated by multiplying U.S. cold storage stocks (Table A-8) by California's proportion of U.S. calendar year pack for the corresponding period.

Source: Computed from data in Tables A-7, A-8, and A-4.

TABLE A-12

United States Imports of Fresh Brussels Sprouts, by Origin, Apparent Fresh Exports, and Frozen Imports, Fiscal Years 1963-1964 to 1967-1968

Fiscal year	Fresh imports: Imports under quarantine a/ Mexico	Fresh imports: Imports under quarantine a/ Other	Fresh imports: Imports under quarantine a/ Total	Fresh imports: Recorded rail and truck movement from Mexico b/ To U.S.	Fresh imports: Recorded rail and truck movement from Mexico b/ To Canada	Fresh imports: Recorded rail and truck movement from Mexico b/ Total	Fresh imports: Mexican imports unaccounted for c/	Recorded truck movement, California to Canada b/	Frozen imports under quarantine a/ d/
	1	2	3	4	5	6	7	8	9
	1,000 pounds								
1963-1964	1,887	--	1,887	900	23	923	987	1,125	194
1964-1965	1,808	30	1,838	788	--	788	1,020	1,035	331
1965-1966	4,506	119	4,625	1,485	270	1,755	2,751	585	372
1966-1967	2,325	58	2,383	653	180	833	2,492	900	187
1967-1968	4,363	125	4,489	2,498	810	3,308	1,055	630	153

a/ Brussels sprouts may be imported into the United States in bulk containers, repacked and sold in the U.S., or reexported without a label identifying their foreign origin. No data are available to show the extent of such handling.

b/ Converted from carlots to pounds at 22,500 pounds per carlot equivalent.

c/ Column 1 less column 6.

d/ Frozen imports originate primarily in Belgium and the Netherlands.

Source: Compiled or computed from California Federal-State Market News Service, *Marketing California Brussels Sprouts*, 1967-1968 summary.

Frozen Brussels Sprouts: California F.O.B. Price Quotations for Grade A, 8- to 10-Ounce Packages, 1947-1968[a/]

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	dollars per dozen packages											
1947	2.25-2.40	→ b/	→	→	→		1.85-2.70				2.30-2.45	2.25-2.40
1948	2.30-2.40	2.15-2.30						2.40	2.25-2.40	2.25-2.40	2.50-2.55	2.30-2.55
1949	2.45-2.50	→	→	→	→	→	→	→	2.20-2.40	2.30-2.35	2.30-2.40	2.20-2.35
1950	2.20-2.30	2.20-2.35	→	2.30-2.35	→	2.65-2.70	2.55-2.60	2.45	2.40	2.20-2.25	2.15-2.35	2.30-2.35
1951	2.30-2.35	→	→	→	→	→	→	→	2.20	2.10-2.35	2.20-2.45	1.92-2.05
1952	1.85-2.05	1.85-2.00	1.75-2.00	→	1.75-1.95	→	→	→	1.95-2.12	2.05	2.05-2.10	2.05-2.15
1953	2.05-2.15	2.05-2.10	→	→	2.20-2.50				2.20	2.05-2.15	2.10-2.15	
1954				2.15-2.20	2.15-2.25	→	→	2.15-2.20	1.80-2.00	1.90-1.95	→	1.80-1.85
1955	1.72-1.85	→	→	→	→	→	1.55-1.85	→	→	1.75-1.85	→	→
1956	1.85-2.05	→	2.05	1.80-1.85	→	→	→	→	1.65-2.00	→	→	→
1957	1.65-2.00	→	→	→	→	→	→	1.60-2.00	→	1.65-2.00	→	→
1958	1.55-2.00	→	→	→	1.60-2.10	→	→	→	→	→	→	→
1959	1.85-2.10	2.05-2.35	→	→	→	→	→	→	1.80-2.00	→	→	→
1960	1.80-2.00	→	→	1.90-2.25	1.90-2.25		2.10-2.40	→	1.98-2.40	→	→	→
1961	1.98-2.40	→	→	→	→	→	→	→	→	1.90-2.10	→	→
1962	1.90-2.10	→	→	→	→	→	→	→	→	→	1.60-1.90	→
1963	1.60-1.90	→	→	→	1.65-2.05	→	1.75-2.15	→	→	1.63-2.00	→	1.68-2.08
1964	1.68-2.08	→	→	1.75-2.15	→	→	→	→	1.65-2.05	→	1.70-2.15	→
1965	1.70-2.15	→	→	→	→	→	→	→	→	→	1.85-2.25	1.95-2.35
1966	1.95-2.35	→	2.05-2.45	→	→	2.10-2.55	→	→	→	→	→	→
1967	2.10-2.55	→	→	→	→	→	→	2.45	2.45	2.45	2.35	2.35
1968	2.35	2.35	2.35		2.35-2.37	2.35	2.35				2.47	2.47

a/ Quotations through August 1956 are for 10-ounce packages. Thereafter they refer to 8- to 10-ounce packages.

b/ Arrow indicates continuation of previous quotation.

Source: *Quick Frozen Foods*, monthly issues, E. W. Williams Publications, New York.

TABLE A-14

Frozen Brussels Sprouts: Midpoint Value of Monthly California F.O.B. Price Quotations, Grade A, 10-ounce Packages, Converted to Cents per Pound, 1947-1968 a/

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	cents per pound											
1947	31.00	→ b/	→	→	→	30.67 c/	30.33	30.67 c/	31.00 c/	31.33 c/	31.67	31.67
1948	31.33	29.67	30.83 c/	32.17 c/	33.41 c/	34.67	33.33 c/	32.00	31.00	31.00	33.67	32.33
1949	33.00	→	→	→	→	→	→	31.84 c/	30.67	31.00	31.33	30.33
1950	30.00	30.33	30.33	31.00	31.00	35.67	34.33	32.67	32.00	29.67	30.00	31.00
1951	31.00	→	→	→	→	→	→	→	29.33	29.67	31.00	26.47
1952	26.00	25.67	25.00	25.00	24.67	→	→	→	27.13	27.33	27.67	28.00
1953	28.00	27.67	→	→	31.33	30.84 c/	30.33	29.84	29.33	28.00	28.33	28.47
1954	28.60 c/	28.73 c/	28.87 c/	29.00	29.33	→	→	29.00	25.33	25.67	25.67	24.33
1955	23.80	→	→	→	→	→	22.67	→	→	24.00	→	→
1956	26.00	26.00	27.33	24.33	→	→	→	→	25.51	→	→	→
1957	25.51	→	→	→	→	→	→	25.33	25.33	25.51	→	→
1958	25.97	→	→	→	26.33	→	→	→	→	→	→	→
1959	27.17	30.33	→	→	→	→	→	→	26.00	→	→	→
1960	26.00	→	→	28.84	28.84	29.92	31.00	31.00	30.60	→	→	→
1961	30.60	→	→	→	→	→	→	→	→	27.33	→	→
1962	27.33	→	→	→	→	→	→	→	→	→	24.33	24.33
1963	24.33	→	→	→	26.00	26.00	27.33	→	→	25.44	25.44	26.40
1964	26.40	→	→	27.33	→	→	→	→	26.00	26.00	27.17	27.17
1965	27.17	→	→	→	→	→	→	→	→	→	28.67	30.00
1966	30.00	30.00	31.33	→	→	32.51	→	→	→	→	→	→
1967	32.51	→	→	→	→	→	→	32.67	→	→	31.33	31.33
1968	31.33	31.33	31.33		31.47	31.33	31.33				32.93	32.93

a/ The quotation range for 10-ounce packages only during 1947-1956 varied from 5 to 20 cents. From September 1956 on the quotations were given for 8- to 10-ounce packages and varied from about 20 to 40 cents. Since the average range about doubled for the 8- to 10-ounce quotations (extending downward only), one-fourth of the range was subtracted from the upper bound, starting in 1957, to obtain the selected value. This adjusts the series to more closely reflect the midpoint value that would have been obtained if prices had been quoted for 10-ounce packages only.

b/ Arrows indicate continuation of previous quotation.

c/ Interpolated value.

Source: Table A-11.

TABLE A-15

Frozen Brussels Sprouts: California F.O.B. Price Quotations for Grade A, 32- or 40-Ounce Packages, 1947-1968 a/

Year	Size class b/	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
		cents per pound											
1947		25.0-27.0	25.0	25.0-29.0	24.0-28.0	24.0-28.0						27.5-30.0	25.5-27.5
1948		26.5-29.0	25.5-28.0		26.0-27.0				29.0	27.0-29.0	27.0-29.0	28.0-29.0	28.0-30.0
1949		28.0-30.0	29.0-30.0	→ c/	→	→	→	→		28.0	27.0	26.5-27.5	26.5-27.0
1950		26.0-27.5	27.0	27.0	27.5	27.0-28.0	26.0-28.0	27.0-28.0	28.0	28.0	25.0-27.0	20.0-25.0	24.0-26.0
1951		24.0-26.0	→	→	→	→	→	→	→	→	→	24.0-27.0	22.0-24.0
1952		18.5-20.0	20.0-22.0	20.0-21.0	19.0-22.0	20.0-21.0	20.0-22.0	20.0-21.0	20.0-21.0	23.0-24.0	23.5	23.5-24.0	23.5-24.0
1953		23.0-24.0	22.0-24.0	22.0-24.0	23.0-24.0	26.0				26.5	24.0-25.0	25.0-25.5	25.5
1954		25.5	25.5	25.5	25.0	25.0	25.5-26.0	→	→	→	22.0-25.0	22.0-25.0	22.0-23.0
1955		22.0-23.0	20.0-23.0	22.0-23.0	18.0-22.0	18.0-20.0	20.0-22.0	18.0-20.0	18.0-20.0	18.0-20.0	20.5-22.0	20.5-22.0	20.5-22.0
1956	40- 60	18.5-19.0	18.5-19.0	23.5	21.5-23.0	→	→	→	→	→	→	→	→
	60- 80	20.5-22.0	20.5-22.0	25.0-26.0						24.0-25.0	→	→	→
	80-100	22.0-24.0	22.0-24.0	26.0-28.0	25.5-27.0	→	→	→	→	28.0	→	→	→
1957	40- 60	21.5-23.0	21.5	→	→	→	→	→	20.0-21.0	→	→	→	→
	60- 80	24.0-25.0	23.0	→	→	→	→	→	21.0-22.0	→	→	→	→
	80-100	28.0	24.0-25.0	→	→	→	→	→	23.0	→	→	→	→
1958	40- 60	18.0-19.0	→	→	→	21.0-22.0	→	→	→	→	→	→	→
	60- 80	21.0-22.0	→	→	→	21.0-23.0	→	→	→	→	→	→	→
	80-100	23.0	→	→	→	23.0-24.0	→	→	→	→	→	→	→
1959	40- 60	21.0-22.0	23.5-24.0	→	→	→	→	→	→	21.0-22.0	→	→	→
	60- 80	21.0-23.0	24.5-25.0	→	→	→	→	→	→	22.0-23.0	→	→	→
	80-100	23.0-24.0	25.0-26.0	→	→	→	→	→	→	24.0-25.0	→	→	→
1960	40- 60	21.0-22.0	→	→	23.0-23.5	→	→	→	→	→	→	→	→
	60- 80	22.0-23.0	→	→	24.0	→	→	25.0	→	→	→	→	→
	80-100	24.0-25.0	→	→	25.0	→	→	26.0-29.0	26.0-29.0	26.0-27.0	→	→	→
1961	40- 60	23.0-23.5	→	→	→	→	→	→	→	→	→	→	→
	60- 80	25.0	→	→	→	→	→	→	→	→	→	→	→
	80-100 d/	26.0-27.0	→	→	→	→	→	→	→	→	→	→	→
1962	40- 60	23.0-23.5	→	→	→	→	→	→	→	→	→	→	→
	60- 80	25.0	→	→	→	→	→	→	→	→	→	→	→
	80-100 d/	26.0-27.0	→	→	→	→	→	→	→	→	→	→	→
1963	40- 60	23.0-23.5	→	→	→	→	→	→	→	→	20.0-23.5	→	→
	60- 80	25.0	→	→	→	→	→	→	→	→	26.0	→	→
	80-100	26.0-27.0	→	→	→	→	→	→	→	→	27.5-28.0	→	→
1964	40- 60	20.0-23.5	→	→	→	→	→	→	→	21.0-22.0	→	→	→
	60- 80	26.0	→	→	→	→	→	→	→	25.0-26.0	→	→	→
	80-100	27.5-28.0	→	→	→	→	→	→	→	27.0-28.0	→	→	→
1965	40- 60	21.0-22.0	→	→	→	→	→	→	→	→	→	→	→
	60- 80	25.0-26.0	→	→	→	→	→	→	→	→	→	26.0-27.0	26.0-27.0
	80-100	27.0-28.0	→	→	→	→	→	→	→	→	28.0-29.0	28.0-29.0	29.0-30.0
1966	40- 60	21.0-22.0	→	→	→	→	→	→	→	→	→	→	→
	60- 80	26.0-27.0	→	→	→	→	→	→	→	→	→	→	→
	80-100	29.0-30.0	→	→	→	→	→	→	→	→	→	→	→
1967	40- 60	21.0-22.0	→	→	→	→		23.0-24.0		22.0-23.0			
	60- 80	26.0-27.0	→	→	→	→	27.0-29.0	26.0-27.0	27.0-29.0	22.0-24.0	28.0-31.0	24.0-31.0	24.0-31.0
	80-100	29.0-30.0	→	→	→	→	29.0-32.0	30.0-32.0	29.0-32.0	31.0			
1968	e/	28.0-32.0	→	→	→	→	27.0-32.0	27.0-32.0				30.0	

a/ Mostly 32-ounce packages.

b/ Size groupings are in terms of number of sprouts per 32-ounce package. Prior to 1956, the price quotations did not indicate sprout size.

c/ Arrow indicates continuation of previous quotation.

d/ Quoted as 90-120.

e/ Size not specified.

Source: *Quick Frozen Foods*, monthly issues, E. W. Williams Publications, New York.

TABLE A-16

Frozen Brussels Sprouts: California F.O.B. Price Quotation for Grade A, 32- or 40-Ounce Packages, 1947-1968a/

Year	Size class b/	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Calendar year average	Crop year average (Sept.-Aug.)
		cents per pound													
1947		26.00	25.00	27.00	26.00	26.00	26.45c/	26.90c/	27.35c/	27.80c/	28.25c/	28.75	26.50	26.83	27.60
1948		27.75	26.75	26.62c/	26.50	27.12c/	27.75c/	28.37c/	29.00	28.00	28.00	28.50	29.00	27.78	29.02
1949		29.00	29.50	→ d/	→	→	→	→	28.75c/	28.00	27.00	27.00	26.75	28.62	27.25
1950		26.75	27.00	27.00	27.50	27.50	27.00	27.50	28.00	28.00	26.00	22.50	25.00	26.64	25.12
1951		25.00	→	→	→	→	→	→	→	→	→	25.50	23.00	24.87	21.85
1952		19.25	21.00	20.50	20.50	20.50	21.00	20.50	20.50	23.50	23.50	23.75	23.75	21.52	24.35
1953		23.50	23.00	23.00	23.50	26.00	26.12c/	26.25c/	26.37c/	26.50	24.50	25.25	25.50	24.96	25.46
1954		25.50	→	→	25.00	25.00	25.75	→	→	→	23.50	23.50	22.50	24.92	21.73
1955		22.50	21.50	22.50	20.00	20.00	21.00	19.00	19.00	19.00	21.25	21.25	21.25	20.69	23.08e/
1956	40- 60	18.75	18.75	23.50	22.25	→	→	→	→	22.25	→	→	→	21.77	21.73
	60- 80	21.25	21.25	25.50	25.42c/	25.34c/	25.26c/	25.18c/	25.08c/	25.00	→	→	→	24.52	23.71
	80-100	23.00	23.00	27.00	26.25	→	→	→	→	28.00	→	→	→	26.35	25.83
1957	40- 60	22.25	21.50	→	→	→	→	→	20.50	→	→	→	→	21.15	20.17
	60- 80	25.00	23.00	→	→	→	→	→	21.50	→	→	→	→	22.54	21.67
	80-100	28.00	24.50	→	→	→	→	→	23.00	→	→	→	→	24.17	23.17
1958	40- 60	18.50	→	→	→	21.50	→	→	→	→	→	→	→	20.50	22.81
	60- 80	21.50	→	→	→	22.00	→	→	→	→	→	→	→	21.83	23.60
	80-100	23.00	→	→	→	23.50	→	→	→	→	→	→	→	23.33	24.67
1959	40- 60	21.50	23.75	→	→	→	→	→	→	21.50	→	→	→	22.81	22.23
	60- 80	22.00	24.75	→	→	→	→	→	→	22.50	→	→	→	23.77	23.29
	80-100	23.50	25.50	→	→	→	→	→	→	24.50	→	→	→	25.00	25.12
1960	40- 60	21.50	→	→	23.25	→	→	→	→	→	→	→	→	22.81	23.25
	60- 80	22.50	→	→	24.00	→	→	25.00	→	→	→	→	→	24.12	25.00
	80-100	24.50	→	→	25.00	→	→	27.50	27.50	26.50	→	→	→	25.79	26.50
1961	40- 60	23.25	→	→	→	→	→	→	→	→	→	→	→	23.25	23.25
	60- 80	25.00	→	→	→	→	→	→	→	→	→	→	→	25.00	25.00
	80-100	26.50	→	→	→	→	→	→	→	→	→	→	→	26.50	26.50
1962	40- 60	23.25	→	→	→	→	→	→	→	→	→	→	→	23.25	23.25
	60- 80	25.00	→	→	→	→	→	→	→	→	→	→	→	25.00	25.00
	80-100	26.50	→	→	→	→	→	→	→	→	→	→	→	26.50	26.50
1963	40- 60	23.25	→	→	→	→	→	→	→	→	21.75	→	→	22.87	21.87
	60- 80	25.00	→	→	→	→	→	→	→	→	26.00	→	→	25.25	25.92
	80-100	26.50	→	→	→	→	→	→	→	→	27.75	→	→	26.81	27.64
1964	40- 60	21.75	→	→	→	→	→	→	→	21.50	→	→	→	21.67	21.50
	60- 80	26.00	→	→	→	→	→	→	→	25.50	→	→	→	25.83	25.50
	80-100	27.75	→	→	→	→	→	→	→	27.50	→	→	→	27.67	27.50
1965	40- 60	21.50	→	→	→	→	→	→	→	→	→	→	→	21.50	21.50
	60- 80	25.50	→	→	→	→	→	→	→	→	→	26.50	26.50	25.67	26.33
	80-100	27.50	→	→	→	→	→	→	→	→	28.50	28.50	29.50	27.83	29.17
1966	40- 60	21.50	→	→	→	→	→	→	→	→	→	→	→	21.50	21.89
	60- 80	26.50	→	→	→	→	→	→	→	→	→	→	→	26.50	26.75
	80-100	29.50	→	→	→	→	→	→	→	→	→	→	→	29.50	29.79
1967	40- 60	21.50	→	→	→	→	22.50c/	23.50	23.00c/	22.50					
	60- 80	26.50	→	→	→	→	28.00	26.50	28.00	23.00	29.50	27.50	27.50	26.88	28.83
	80-100	29.50	→	→	→	→	30.50	31.00	30.50	31.00					
1968	f/	30.00	→	→	→	→	29.50	29.50				30.00			

a/ Mostly 32-ounce packages.

b/ Size groupings are in terms of number of sprouts per 32-ounce package. Prior to 1956, the price quotations did not indicate sprout size.

c/ Interpolated value.

d/ Arrow indicates continuation of previous quotation.

e/ Average for 60-80.

f/ Size not specified.

Source: Table A-13.

TABLE A-17

Monthly Prices and Quantities of Frozen Brussels Sprouts
from 1961-1962 Freezer Survey a/

Month starting January 1961	Price						Quantity					
	Retail size packages b/			Institutional size packages c/			Retail size packages			Institutional size packages		
	Large	Medium	Small	Large	Medium	Small	Large	Medium	Small	Large	Medium	Small
	cents per pound						1,000 pounds					
1	23.8	26.8	28.5	22.3	24.8	26.2	355.2	757.7	247.2	321.6	266.2	76.7
2	24.0	26.8	28.7	22.3	25.2	26.4	277.4	719.1	294.1	140.7	205.5	74.3
3	23.7	27.2	28.4	22.7	25.6	26.6	379.3	880.6	414.9	182.5	239.0	58.4
4	24.2	27.3	28.8	21.6	25.5	26.5	197.0	748.5	190.0	95.3	105.2	28.0
5	24.1	27.1	28.7	23.3	25.7	26.5	98.6	1118.9	176.8	49.5	150.3	57.6
6	24.2	27.0	29.5	21.8	25.9	27.1	30.3	749.2	177.5	142.1	152.1	19.5
7	24.4	27.3	29.3	23.4	25.6	26.9	176.8	843.1	110.1	22.9	168.0	14.2
8	24.8	27.4	29.3	21.0	25.6	26.7	74.1	469.1	169.3	209.2	101.9	45.0
9	23.8	27.0	28.8	21.6	24.7	26.6	90.7	984.7	265.2	408.8	442.9	18.2
10	23.7	26.6	28.6	21.3	24.8	26.6	166.5	1013.1	223.5	408.8	358.6	46.1
11	23.5	26.8	28.6	21.4	24.8	26.7	116.5	625.9	267.1	171.8	490.5	36.1
12	24.0	26.5	28.5	21.2	24.4	26.7	209.0	933.7	183.9	482.6	443.9	41.4
13	24.0	26.8	28.7	22.9	25.0	26.3	245.1	945.1	127.2	169.7	265.1	79.4
14	24.2	26.8	28.5	22.5	25.4	26.7	177.6	809.5	324.2	141.2	247.5	23.8
15	23.5	26.9	28.7	22.8	25.3	26.3	237.2	1023.3	324.5	174.9	256.9	51.0
16	23.2	26.8	29.2	21.9	25.8	26.6	155.2	899.1	196.8	64.4	180.9	10.7
17	23.7	27.0	28.6	22.8	25.7	26.7	61.8	1039.1	217.9	28.0	177.8	29.8
18	24.0	27.2	29.3	22.4	25.8	26.5	61.5	782.3	168.5	108.9	173.3	23.8
19	24.2	27.2	29.1	22.9	25.7	26.7	92.2	848.6	113.3	49.7	194.4	17.6
20	23.8	27.5	28.6	22.8	25.5	27.0	102.2	511.8	153.2	171.8	165.2	17.7
21	23.2	26.7	28.5	21.2	24.6	26.5	199.3	909.5	231.4	534.9	559.2	38.8
22	23.4	26.7	28.5	22.2	24.8	26.6	143.8	1008.3	165.1	179.1	286.3	45.4
23	23.1	26.3	28.4	22.3	24.8	26.5	194.1	846.0	210.4	222.5	397.5	33.1
24	23.4	26.1	27.8	21.4	24.9	26.7	155.2	830.8	275.1	271.0	398.5	21.8

a/ Prices and quantities are for freezers accounting for approximately 65 percent of the California pack during 1961 and 1962. Size groupings were established on a trimmed basis as follows: Large - less than 25 per pound and including B grade, Medium - 25 to 40 per pound, and Small - over 40 per pound.

b/ Retail size packages include all sizes of one pound and under.

c/ Institutional size packages include all sizes over one pound.

TABLE A-18

Brussels Sprouts: Annual Average Prices Received by Growers and F.O.B. Price Quotations by California Freezers, 1947-1968

Year	Average price received by growers, fresh and processed			Adjusted California grower price b/	Adjusted California grower price c/	Average F.O.B. California processor price for frozen Brussels sprouts, Grade A quality			
						Crop year (September - August)		Calendar year	
	California a/	New York	U.S.			10-oz. packages	32-oz. packages d/	10-oz. packages	32-oz. packages d/
	cents per pound - raw product weight				cents per pound - frozen product weight				
1947					12.28 e/	31.87	27.60	30.97	26.83
1948					12.28 e/	32.57	29.02	32.12	27.78
1949	10.94	11.00	10.99	10.94	12.82	31.56	27.25	32.19	28.62
1950	10.03	10.24	10.00	10.03	11.76	30.89	25.12	31.49	26.64
1951	9.70	11.28	9.87	9.85	11.54	26.40	21.85	30.37	24.87
1952	10.24	14.76	10.64	10.42	12.21	28.63	24.35	25.87	21.52
1953	9.84	12.57	10.01	10.04	11.77	28.85	25.46	28.96	24.96
1954	6.99	11.67	7.26	7.17	8.40	24.09	21.73	27.76	24.92
1955	7.93	12.96	8.26	8.13	9.53	24.64	23.08	23.57	20.69
1956	8.08	10.78	8.25	8.29	9.72	25.49	23.71	25.25	24.52
1957	6.44	9.75	6.70	6.62	7.76	25.92	21.67	25.48	22.54
1958	8.08	12.80	8.50	8.30	9.73	28.73	23.60	26.21	21.83
1959	7.98	11.57	8.30	8.17	9.56	27.63	23.29	28.63	23.77
1960	8.78	10.43	8.91	8.99	10.54	30.60	25.00	29.17	24.12
1961	9.29	8.66	9.25	9.50	11.13	27.60	25.00	29.79	25.00
1962	10.46	9.10	10.36	10.67	12.51	25.61	25.00	26.83	25.00
1963	10.30	7.02	10.01	10.51	12.32	26.71	25.92	25.72	25.25
1964	11.03	6.66	10.62	11.03	12.93	26.97	25.50	26.85	25.83
1965	12.51	8.35	11.98	12.51	14.66	30.37	26.33	27.53	25.67
1966	12.40	7.33	11.86	12.40	14.53	32.52	26.75	31.80	26.50
1967	11.78	8.43	11.19	11.78	13.81	31.33	28.83	32.35	26.88
1968	12.21	7.54		12.21	14.31	32.30		31.78	

a/ Fresh market on F.O.B. packed and loaded basis. Frozen first delivery point until 1964; from 1964 on at processing plant door. Grower prices are for the crop year.

b/ 1949-1963 values increased to reflect 30 cents per cwt. hauling cost for proportion of crop sold to processors. This roughly adjusts total series to processing plant door for sales to freezers.

c/ Farm price multiplied by conversion factor of 1.172. This adjusts to approximately a frozen weight basis. This gives an indication of processor raw product cost. However, since the grower price includes fresh sales, it is only an approximation. Prices paid by processors are not published separately.

d/ Sprout size not specified prior to 1955. Thereafter prices are for 60-80 per 32-ounce package. Sprout size for retail packages is not specified for any years.

e/ Average of 1949 and 1950.

Source: Grower prices from U.S. Department of Agriculture, Statistical Reporting Service, *Vegetables for Fresh Market*, statistical summaries, Crop Reporting Board, Washington, D.C. Processor prices computed from Tables A-12 and A-14.

TABLE A-19

United States Per Capita Disappearance of Brussels Sprouts and Consumption of Competing Fresh and Frozen Vegetables, 1947-1968

Year	Disappearance from domestic Brussels sprouts production				Total per capita vegetable consumption (excluding potatoes)[a]			
	Frozen		Fresh	Total	Frozen	Fresh	Canned	Total
	Final product weight	Raw product weight[b]	Raw product weight[c]		Retail weight			
	pounds							
1947	.048	.056	.250	.306	2.57	103.0	39.8	145.4
1948	.085	.100	.200	.300	2.93	103.8	37.4	144.1
1949	.121	.142	.133	.275	2.94	97.9	38.3	139.1
1950	.118	.138	.142	.280	3.26	97.3	41.2	141.8
1951	.149	.175	.177	.352	4.08	94.1	41.5	139.7
1952	.167	.196	.099	.295	4.92	93.8	40.8	139.5
1953	.205	.240	.131	.371	5.12	92.7	42.2	140.0
1954	.177	.208	.175	.383	5.55	91.4	41.1	138.0
1955	.193	.226	.113	.339	5.90	90.7	42.2	138.8
1956	.229	.269	.136	.405	6.06	93.4	42.7	142.2
1957	.194	.228	.159	.387	6.28	93.9	42.9	143.1
1958	.190	.223	.113	.336	6.63	92.3	43.5	142.4
1959	.208	.244	.157	.401	6.84	91.7	43.6	142.1
1960	.200	.235	.140	.375	6.98	96.1	43.4	146.5
1961	.211	.248	.119	.367	6.94	94.8	43.5	145.2
1962	.224	.263	.108	.371	7.44	93.4	45.1	145.9
1963	.208	.244	.110	.354	7.16	93.4	45.9	146.5
1964	.246	.289	.103	.392	7.60	90.8	45.5	143.9
1965	.221	.259	.085	.344	8.07	90.6	46.8	145.5
1966	.204	.239	.084	.323	8.80	90.7	47.0	146.5
1967	.238	.279	.097	.376	9.03	91.1	48.9	149.0
1968[d]	.236	.277	.083	.360	9.04	91.0	48.6	148.4

a/ Civilian consumption.

b/ Converted from final product to raw product by an average ratio of 1.173.

c/ Estimated crop year production (Table A-3) divided by January 1, 50-state population (including armed forces) of indicated crop year.

d/ Preliminary value.

Source: Brussels sprouts estimates computed from data published in U.S. Department of Agriculture, *Cold Storage Reports*, National Association of Frozen Food Packers, annual statistical reports; U.S. Department of Agriculture, Crop Reporting Service estimates; and California Federal-State Market News Service, *Marketing California Brussels Sprouts*, annual issues. Other vegetable consumption data are from U.S. Department of Agriculture, Economic Research Service, *Food, Consumption, Prices, Expenditures*, Agricultural Economics Report, No. 138, July 1968; and U.S. Department of Agriculture, Economic Research Service, *The Vegetable Situation*, TVS-170, October 1968.

TABLE A-20

Selected Economic Variables Influencing Consumption and Prices of Frozen Vegetables

Year	U.S. per capita disposable income[a]	U.S. per capita food expenditures[a]	Proportion of U.S. homes with refrigerators[b]	U.S. total population on Dec. 31[c]	Index of purchasing power for frozen vegetables[d]	Index of prices received by processors for frozen vegetables[e]
	1957-1959 = 100			millions	1957-1959 = 100	
1947	63.9	79.6	.712	146.0	56.7	112.4
1948	69.9	83.0	.766	148.6	63.6	119.5
1949	68.5	78.8	.792	151.1	62.4	115.9
1950	73.9	79.6	.864	153.6	68.8	110.3
1951	79.9	88.8	.867	156.3	77.0	115.5
1952	82.2	91.4	.892	159.0	81.5	113.1
1953	85.7	91.1	.904	161.7	82.4	113.3
1954	85.9	91.4	.925	164.6	84.5	105.1
1955	90.2	92.2	.941	167.5	86.8	105.9
1956	94.4	94.3	.960	170.6	90.5	107.9
1957	97.6	98.0	.973	173.5	95.4	97.7
1958	99.2	100.6	.977	176.4	98.3	100.4
1959	103.2	101.4	.980	179.4	99.4	101.9
1960	104.9	101.9	.980	182.3	99.9	106.6
1961	107.6	103.0	.983	185.3	101.2	103.4
1962	111.8	104.5	.995	188.2	104.0	96.8
1963	115.7	106.1	.995	190.9	105.6	97.3
1964	123.5	110.0	.995	193.5	109.5	97.8
1965	131.7	115.8	.995	195.9	115.2	99.6
1966	140.7	123.7	.995	198.1	123.1	105.3
1967	148.6	125.3	.996	200.2	124.8	
1968	158.2	132.1	.996	202.3	131.6	

a/ Data from U.S. Department of Agriculture, Economic Research Service, *Working Data for Demand Analysis*, revision of October 1968.

b/ Data from National Industrial Conference Board, *Economic Almanac*.

c/ Fifty-state population including armed forces overseas. Bureau of the Census, Series P-25.

d/ United States per capita food expenditures multiplied by proportion of U.S. homes with refrigerators.

e/ Computed from annual average F.O.B. freezer price quotations for Grade A retail size containers for the following vegetables: lima beans, green beans, broccoli, Brussels sprouts, cauliflower, corn, peas, and spinach. Index is weighted by quantities sold in 1957-1959. Prices were computed from price data given in *Quick Frozen Foods*, E. W. Williams Publications, New York.

TABLE A-21

Estimated Costs of Growing and Freezing
Brussels Sprouts, 1947-1968

Year	Grower cost[a/]	Index of vegetable freezing costs[b/]	Projected costs of freezing Brussels sprouts[c/]
	cents per pound	1947-1949 = 100	cents per pound
1947	7.3	98.7	12.70
1948	7.3	101.8	13.10
1949	7.3	99.6	12.81
1950	7.3	100.8	12.96
1951	7.3	116.1	14.93
1952	7.3	114.0	14.67
1953	7.4	114.0	14.66
1954	7.4	112.1	14.41
1955	7.4	114.2	14.69
1956	7.4	117.1	15.06
1957	7.4	120.6	15.50
1958	7.4	120.2	15.46
1959	7.4	119.8	15.41
1960	7.4	119.8	15.42
1961	7.4	116.4	14.97
1962	7.4	116.9	15.03
1963	8.5	118.0	15.31
1964	9.7	117.4	14.97
1965	10.1	117.5	15.11
1966	10.6	119.5	15.37
1967	11.0	120.6	15.50
1968	11.5		

a/ Interpolated from periodic sample cost studies of the California Agricultural Extension Service. Data obtained from the office of R. H. Sciaroni, San Mateo County Farm Advisor.

b/ Data for 1947-1959 computed from French, Ben C., *Cost and Factor Price Changes in the Vegetable Producing and Processing Industries, 1947-49*, Berkeley: University of California, Agricultural Experiment Station, Giannini Foundation Research Report No. 241, March 1961. The index for the period since 1959 was extended by the authors. Weights used for components were revised on the basis of data in the 1965 NCFM survey (Labor .41, Capital .18, Material .41).

c/ 1963-1964 NCFM average California freezing costs (excluding raw product) adjusted by index of vegetable freezing cost. 1963-1964 NCFM cost data are given in Table 7.

TABLE A-22

Estimates of United States and Regional Crop Year Disappearance of Frozen Brussels Sprouts, 1947-1968

Year	U.S. crop year pack	U.S. cold storage stocks		Disappearance Aug. 1 - July 31		
		July 31	Aug. 31	U.S.[a]	California[b]	Other[c]
	million pounds					
1947	5.237	4.759	4.700	7.028	6.522	.506
1948	11.453	2.968	2.304	12.622	12.155	.467
1949	23.319	1.799	1.272	18.252	17.850	.402
1950	20.727	6.866	6.454	18.088	16.677	1.411
1951	22.383	9.507	8.576	23.288	22.124	1.164
1952	23.851	8.602	6.959	26.586	25.815	.771
1953	40.792	5.867	4.618	33.222	31.926	1.296
1954	30.659	13.437	12.049	29.122	27.316	1.806
1955	24.585	14.974	12.816	32.842	32.087	.755
1956	46.019	6.717	5.359	38.395	36.629	1.766
1957	30.143	14.341	13.609	33.660	31.203	2.457
1958	32.465	10.824	9.480	33.552	32.612	.940
1959	34.845	9.737	8.394	37.397	35.752	1.645
1960	39.814	7.185	6.392	36.450	34.628	1.822
1961	42.165	10.549	10.538	39.108	37.113	1.995
1962	40.328	13.606	11.301	42.155	39.584	2.571
1963	41.605	11.779	9.920	39.710	36.493	3.217
1964	47.107	13.674	10.903	47.596	41.837	5.759
1965	42.425	13.185	10.217	43.260	37.852	5.408
1966	48.820	12.350	12.375	40.454	34.993	5.461
1967	45.555	20.716	17.345	47.618	40.809	6.809
1968[d]	43.415	18.653	17.387	45.204	37.655	7.549
1969		16.864	14.705			

a/ Disappearance = pack in t + stocks at beginning of t - stocks at beginning of t + 1.

b/ United States disappearance multiplied by proportion packed in California.

c/ United States disappearance multiplied by proportion packed in regions other than California.

d/ Preliminary value.

Source: Table A-5 and U.S. Department of Agriculture, Economic Research Service, *Cold Storage Reports*.

APPENDIX B

APPENDIX B

Notes on Special Data Calculations

1. Estimation of crop year frozen pack.

United States frozen vegetable pack statistics, reported by the National Association of Frozen Food Packers, are given only on a calendar year basis. For many vegetables the packing season is contained within the calendar year and the crop year and calendar pack are identical. In the case of Brussels sprouts, however, the packing season frequently overlaps two calendar years and the crop year value may, in some years, differ considerably from the calendar year pack. Since crop year values are needed for the statistical analysis it was necessary to develop estimates of crop year pack from the available data.

For the period since 1958, crop year pack values are available for California from the records of the Brussels Sprouts Marketing Program. We have assumed that the frozen vegetable pack in other regions is always completed by January 1. This seems a reasonable approximation in view of more adverse winter weather in other producing regions. Total crop year pack then is obtained by adding the California and other region values.

For the period prior to 1959, crop year data are not readily available from any source that we are aware of. Therefore, we first estimated the United States crop year pack by the procedure described below. Then retaining the assumption that the crop year in regions other than California is contained within a single calendar year, estimates of California crop year pack were obtained by subtracting other region pack from the estimated United States crop year pack.

The value of the United States crop year pack was estimated as follows:

(1) $q_{crpt} = q_{calt} + q_{JF(t+1)} - q_{JFt}$

where q_{crpt} = crop year pack, q_{calt} = calendar year pack (known), and q_{Jf} is pack during January and February. The subscript t refers either to the calendar year or the crop year beginning in that calendar year.

(2) $q_{JFt} = D_{JFt} - S_{J1t} + S_{M1t}$

where D_{JF} = disappearance during January and February, S_{J1} = cold storage stocks as of January 1, and S_{M1} = cold storage stocks as of March 1.

(3) D_{JFt} is not know. It was estimated as $D_{JFt} = 1/6D_t$. That is, January-February disappearance is 1/6 of annual calendar year disappearance. On a crop year basis, January-February movement data for recent years is about 18 percent. However, during periods of increasing consumption (as was the case here), 1/6 may be a reasonable approximation.

(4) Substituting in (1) we obtain

$$q_{crpt} = q_{calt} + 1/6D_{(t+1)} - S_{J1(t+1)} + S_{M1(t+1)}$$
$$- 1/6D_t + S_{J1t} - S_{M1t}$$

or

$$q_{crpt} = q_{calt} + (S_{J1t} - S_{M1t}) - (S_{J1t+1} - S_{M1t+1})$$
$$+ 1/6(D_{t+1} - D_t).$$

2. Determination of crop year disappearance.

Another data problem involved the months to be included in the crop year for purposes of calculating annual sales or disappearance of frozen sprouts. Production of Brussels sprouts usually starts in September and the crop year might reasonably be considered as running from September 1 to August 31. However, occasionally a small amount of production occurs in August and this influences the figures on cold storage holdings at the end of August. Since we do not know how much was produced in August in the earlier years, nor how much of such production was recorded as stored at the end of August in later years, disappearance calculations for the September 1-August 31 period are subject to minor error. To avoid difficulty we shifted the crop year, for purposes of disappearance calculations, to August 1-July 31.

It would seem logical under these circumstances that stock levels, for adjustment and decision purposes, would be measured as of July 31. However, it turned out that using August 31 stock levels, even though subject to small errors, gave much better predictions of supply adjustment. In fact, the accuracy of supply prediction decreased continually as the stock data was moved back toward the spring and summer months. Consequently, we retained August 31 as the date for measuring stock levels. While processors must make some decisions well before August 31, they have reasonably close indications of expected August 31 stocks, even though such figures are not yet formally published when decisions are made.

3. Estimation of regional disappearance of frozen Brussels sprouts.

Published data on cold storage holdings are not detailed as to region in which the stocks were produced. Consequently, there is not way to determine precisely either regional quantities of carry over stocks or the regional quantity of sales for a particular year. Therefore, these values were estimated on the basis of regional shares of pack. That is, for California

$$D_{ct} = \frac{Q_{ct}}{Q_{ust}} D_{ust} \quad , \quad S_{ct} = \frac{Q_{ct-1}}{Q_{ust-1}} S_{ust},$$

and similarly for other region disappearance and stocks--see the section on economics structure for further identification of symbols. Note that S_t refers to stocks held at the beginning of the packing season.

APPENDIX C

APPENDIX C

Determination of the Optimal Distribution Among Size-Container Classes for a Given Total Quantity of Brussels Sprouts

Net Revenue Equation

$$\text{(C1)}\quad NR = \sum_{i=1}^{6} Q_i P_i - \sum_{i=1}^{6} C_i Q_i = \sum_{i=1}^{6} Q_i (b_{oi} + \sum_{j=1}^{6} b_{ij} Q_j) - \sum_{i=1}^{6} C_i Q_i$$

where i refers to a particular size-container class, b_{oi} and b_{ij} are coefficients of the system of demand equations, and C_i is the average cost of producing and processing sprouts in size-container class i.

The unit cost, C_i, may be decomposed into two parts, a constant part, $\bar{C}$, common to all size classes and a variable part, d_i, which varies among size-container classes. Substituting in (C1) gives:

$$\text{(C2)}\quad NR = \sum_{i=1}^{6} Q_i (b_{oi} + \sum_{j=1}^{6} b_{ij} Q_j) - \sum_{i=1}^{6} d_i Q_i - \bar{C} Q.$$

Maximizing Net Revenue

We wish to find the values of Q_i which will maximize (C2) for any given value of Q, the total quantity to be sold. To solve, we form a Lagrangian function, set the first partial derivatives equal to zero, and solve the resulting linear equations for values of Q_i as a function of Q.

$$\text{(C3)}\quad L = \sum_{i=1}^{6} Q_i (b_{oi} + \sum_{j=1}^{6} b_{ij} Q_j) - \sum_{i=1}^{6} d_i Q_i - \bar{C} Q + \lambda(\sum_{i=1}^{6} Q_i - Q).$$

$$\text{(C4)}\quad \frac{\partial L}{\partial Q_i} = b_{oi} + \sum_{j=1}^{6} (b_{ij} + b_{ji}) Q_j - d_i + \lambda = 0.$$

$$\text{(C5)}\quad \frac{\partial L}{\partial \lambda} = \sum_{i=1}^{6} Q_i - Q = 0.$$

To guarantee a maximum, second order conditions require that the bordered Hessian determinant formed from the Lagrangian function be negative definite. Note that $\bar{C}$ (the costs common to all sizes) drops out of the solution equations. Thus we need know only the differences in costs associated with various size categories.

With no other restrictions, our initial solution produced negative values for the quantities in retail-large and institutional-large categories. Since this is clearly not acceptable, it was necessary to add restrictions that would force the quantities in all categories to be greater than or equal to zero. We also considered situations in which quantities in the "large" class were forced to be at least 5 percent and at least 10 percent of the total.[1] With inequality restrictions, the problem becomes a quadratic programming case and solutions may be obtained by quadratic programming procedures. It was clear in this case, however, that the quantity in the "large" class would be at the minimum permitted, so restrictions were imposed as equalities and solutions obtained as before, except with the added restrictions. All other quantities remained positive with these solutions and a check of the original unrestricted solution indicated that they would remain positive for all crop sizes. For large crops, optimum allocations to the "large" class eventually became positive, but this occurs well beyond the range of any crop yet produced.

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1/ To focus on the size distribution problem alone, restrictions were also imposed which maintained the distribution between retail and institutional sizes at average observed (sample) levels (see Table 13).